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4-D COMMON OPERATIONAL PICTURE (COP) FOR MISSION ASSURANCE (4D COP)

Task Order 0001: Air Force Research Laboratory (AFRL) Autonomy Collaboration in Intelligence, Surveillance, and Reconnaissance (ISR), Electronic Warfare (EW)/Cyber and Combat Identification (CID)

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Dialogic Design International

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Final Report

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14. ABSTRACT

Dialogic Design International (DDI) presents a final report for the Autonomy Discovery project, a series of workshops and investigations held between August 2014 and March 2016 to support an autonomy research collaboration aimed at long-term R&D outcomes across AFRL directorates (RY, RH, RI) and AFIT. The project was designed to engage scientific staff from across AFRL in a series of problem-finding (discovery) and problem-solving workshops, expanding stakeholder engagement to build consensus on challenges and future action. A key goal was to inspire collaborations across AFRL for future autonomy programs. The collaboration focused on the uncertainty engendered by the global adoption of advanced emerging technologies and their potential for disruption to roadmaps tied to path-dependency of outdated strategies. These initial collaborative sessions resulted in the discovery of a key problem query: "What bold approaches could AFRL take to address the challenges of Situation Representation used by autonomous learning systems during "pick-up" games in contested or degraded environments toward the goals of merging ISR, EW/Cyber, & Combat ID?" A key finding is that this is critical area of inquiry that will touch on every Air Force mission function and connects across many, if not all, future AFRL R&D programs. Because there have been no "strategic research" collaborations engaging the long-term trajectory of human-machine teaming in autonomous functions across ISR, cyber and air combat, we maintain that there may be considerable risk to program outcomes by under-representing the desired future state of autonomous systems.

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1.0 Summary

Dialogic Design International (DDI) presents a final report for the Autonomy Discovery project, a series of workshops and investigations held between August 2014 and March 2016 to support an autonomy research collaboration aimed at long-term R&D outcomes across AFRL directorates (RY, RH, RI) and AFIT.

The project was designed to engage scientific staff from across AFRL in a series of problem-finding (discovery) and problem-solving workshops, expanding stakeholder engagement to build consensus on challenges and future action. A key goal was to inspire collaborations across AFRL for future autonomy programs. The collaboration focused on the uncertainty engendered by the global adoption of advanced emerging technologies and their potential for disruption to roadmaps tied to path-dependency of outdated strategies. Foresight-driven approaches to R&D planning can mitigate such cost and development risks. As significant technical and research-based controversies will (and have) emerged in autonomy technology development, the collaborative dialogue mediated by the selected method of Structured Dialogic Design (SDD) is well-established for addressing both technical and organizational challenges. These workshop sessions have a twofold purpose, to gain consensus on future planning objectives based on collective understanding of issues, and improve management practice by enhancing the organization's ability to collaborate across disciplinary silos.

DDI was invited to lead a series of engagements for the teams researching autonomous sensing systems in the AFRL. A series of three Structured Dialogic Design^{SM} (SDD) workshops was planned to focus a transdisciplinary inquiry in a selected problem area that emerged from the first two workshops, as described within the report. These initial collaborative sessions resulted in the discovery of a key problem query:

"What bold approaches could AFRL take to address the challenges of Situation Representation used by autonomous learning systems during "pick-up games" in contested or degraded environments toward the goals of merging ISR, EW/Cyber, & Combat ID?"

A key finding is that this is critical area of inquiry that will touch on every Air Force mission function and connects across many, if not all, future AFRL R&D programs. Because there have been no "strategic research" collaborations engaging the long-term trajectory of human-machine teaming in autonomous functions across ISR, cyber and air combat, we maintain that there may be considerable risk to program outcomes by under-representing the desired future state of autonomous systems. We have presented this strategic relationship with a model trajectory (a "qualitative roadmap") that ties this question of situation representation to the integrated capabilities and multi-domain control envisioned for the Third Offset deterrence strategy.

The report is organized as a summary of the entire project to date, primarily presenting outcomes and significant issues of interest to a management audience, rather than a technical report. A detailed set of Appendices provides planning resources, an activity costing, technical discussion, methods, and outcomes. The Appendices also provide unique contributions of the project intended for use in the SDD Collaborative Foresight workshops, including a futures narrative titled *The Situation* and its graphical illustration.

Specifically, this report recommends further collaboration beyond the scope of this project to be pursued among AFRL autonomy investigators and engineers (and relevant external stakeholders). Collaboration pursuant to these recommendations ought to:

- *Focus on leveraging the complex problems of multi-agent situation representation, a theory and modeling of zero-day "pickup game" situations, and understanding the human factors of situational contexts (social meaning making).*
- *Conduct an AFRL steering group (SDD) workshop to develop a group understanding of a problem system of inter-related risks. A leading candidate for the driver in this inquiry is the theory and model of the Pick-Up Game, especially for Anti-Access/Area Denial (A2AD) and emergent, multi-player geopolitical situations.*
- *Use principles of engagement including required variety of stakeholders, continued structured face-to-face dialogue, focus on mid-to-far future horizon and utilize group narrative for problem/solution scoping.*
- *Build upon the precedent and pattern from the exemplary project of the Naval Postgraduate School's Consortium for Robotics and Unmanned Systems Education and Research (CRUSER).*

2.0 Introduction

2.1 Overview and History

The Autonomy Discovery project started in December 2013 with discussions with Dr. Steve Rogers toward the goal of supporting a cross-disciplinary workshop to further develop QUalia Exploitation of Sensing Technology (QuEST) as a basis for the fusion of ISR, EW/Cyber and CID functions in emergent military scenarios. At the outset there was interest in conducting the workshops to address one of the following:

- *QuEST Technology Mapping, to develop long-term QuEST planning and team collaborations;*
- *PC-PADx initiative for integrating robust decision making projects across AFRL; or*
- *Autonomy Community of Interest (COI) initiative, to establish an R&D community (COI) across AFRL and include external stakeholders such as Google, Amazon, and social media services.*

The QuEST option was selected, and DDI planned the workshop series to engage a steering group of autonomy research scientists to "discover" shared issues of interest and identify relevant stakeholders.

The work was supported by Steve Rogers (RY/RI) from its inception and funded by the organizations of Vince Velten (RYAT) and Raj Malhotra (RYAR). The workshop series was organized by Kirk Weigand (RYWA) from the onset with the vision of engaging members from across the enterprise to develop a common technical vision for AFRL autonomy for mission function integration (ISR, EW/Cyber, and CID) over a mid- to long-term timeframe. These Collaborative Foresight workshops are designed to facilitate mixed stakeholder groups to reach consensus on approaches and actions for long-term plans, requiring a collaborative method for engaging collective foresight (futures reasoning) from experts working across disciplinary silos.

Over the course of the project, the following engagements (workshops and meetings) and deliverables have been provided to AFRL and the government.

- ***December 19, 2013*** *Teleconference consultations and report*
- ***September 16, 2014*** - ***Discovery Workshop****, with analysis and report (October 1, 2014)*
- ***December 15, 2014 - Collaborative Foresight Workshop****, with analysis and report (March 23, 2015)*
- ***May 12, 2015*** *– Project Plan for Autonomy Collaboration Workshops*
- ***December 7-10, 2015*** *– Planned date for Workshop 3 (SDD2)*
- ***December 1, 2015 - Pilot Workshop****, analysis and report*
- ***February 2016 –*** *Presentation, future narrative materials, stakeholder analysis, invitations for SDD2*
- ***March 1, 2016 –*** *Contract ended, final report delivered April 30, 2016*

The project plan (February 2016) presented a calendar of precedent engagements, and suggested the two planned SDD events (April and June, 2016), as well as the major intended deliverables, as shown in Figure 1. The workshop series was proposed for jointly developing consensus insights on key challenges, approaches, and common actions leading to a Common Technical Trajectory across ISR, EW/Cyber and CID.

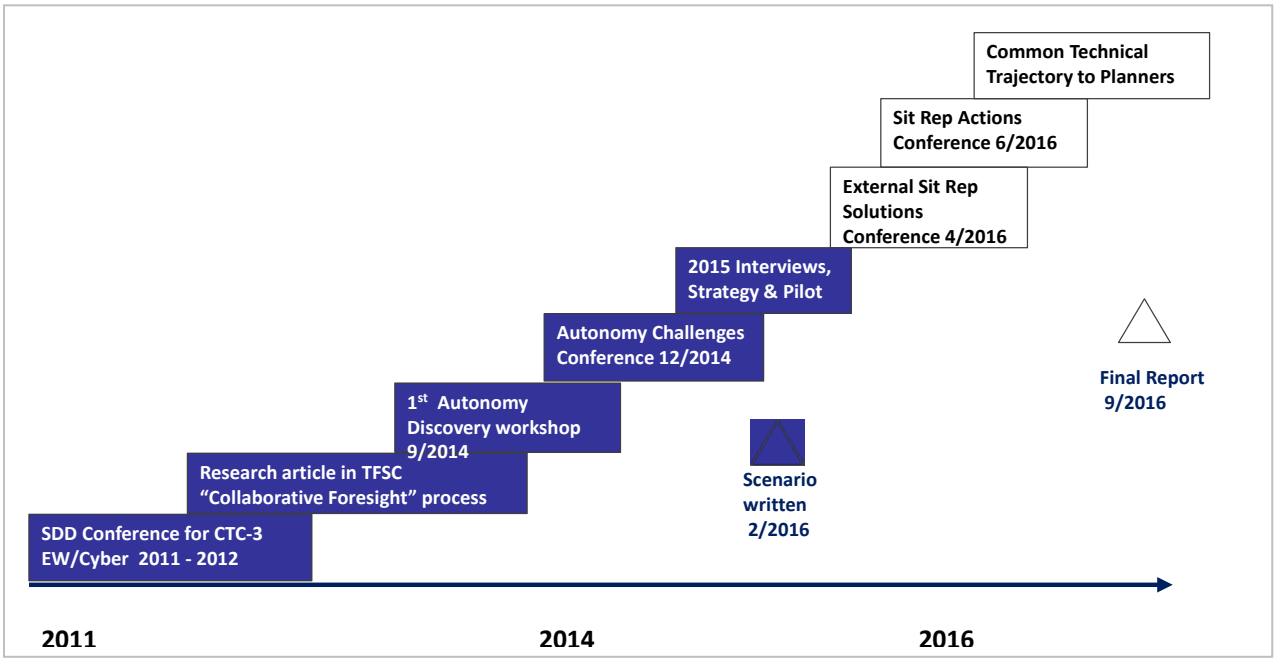

Figure 1. Precedent and Planned Events and Deliverables

The upcoming milestones (white boxes) remain uncompleted, and are represented to illustrate the expected completion of work toward the goal of a unified technical planning product. The overall organizational goal of the effort was to build a resilient working group of AFRL and dedicated Air Force and external experts in the autonomy arena for dealing with core, difficult mid-to-far-term engineering and science problems. These strategic problem areas are well-defined herein, and include the complex problems of multi-agent situation representation, a theory and modeling of zero-day "pickup game" situations, and understanding the human factors of situational contexts (social meaning making).

These longer-term science and technology issues could be considered "high hanging fruit" that would yield research returns over the mid-term (5-10 years), but require immediate attention to make progress. The common technical trajectory is necessary to inform near-term investment for longer-term outcomes.

3.0 Methods, Assumptions and Procedures

3.1 Autonomy Discovery Workshop Results

The focus and direction of the series of engagement session was set by the September 2014 Discovery Workshop that established critical issues and themes analyzed and taken forward into the December 15, 2014 collaborative foresight session. The Discovery workshop was held to identify future challenges and risks across AFRL projects, enabling the DDI team to identify a productive scope for the workshop series and to establish a shared understanding of scope and interests among the steering group.

While the outputs of this initial Discovery workshop might be considered inputs to continuing work, several deliverables were found valuable over the entire project:

- *Three Horizons Map of technology trends and autonomy themes*
- *Category and Theme (taxonomy) Development*
- *Stakeholder Discovery*
- *Initial Influence Map*

3.1.1 Three Horizons Map. The Three Horizons map, shown in Figure 2, and its summary analysis provide a summary of critical autonomy themes.

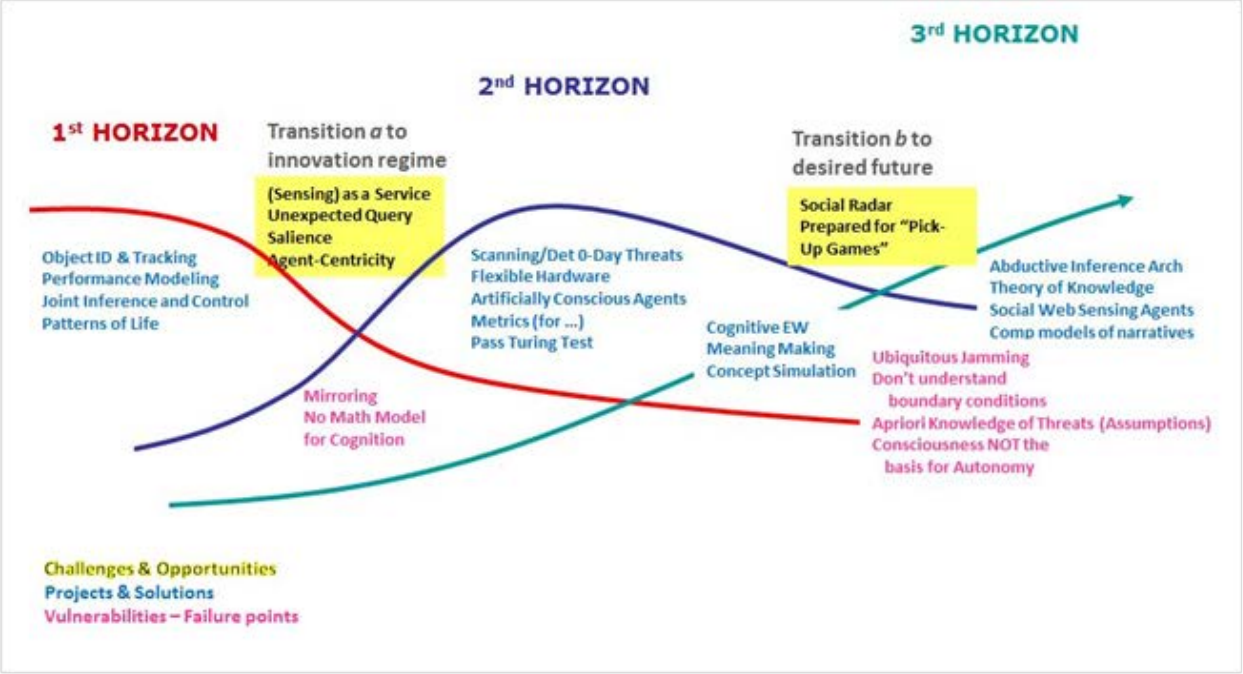

Figure 2. Summary of Three Horizons Workshop Model

Three curves overlap to indicate the prevalence of three trend trajectories in autonomy R&D. The first horizon (H1) represents "business as usual," the dominant trends that will quickly decline if adhered to in the rapidly changing environment.

Horizon 3 (H3) is located in what we might call Far Term, but it is viewed as the desired future outcomes and value to stakeholders sharing the joint initiatives. During the

Discovery workshop this future outcome was not (yet) associated with the Third Offset deterrence strategy, but in hindsight, following recent proposals in late 2015, this would make an appropriate outcome for H3.

Hodgson's (1) Three Horizons systems model shows that H3 goals cannot be accomplished by extrapolation from a present H1 trend line. The transition to Horizon 2 (H2) must be negotiated near term, representing a risk in navigating the shift and bridging to the next innovation regime. Horizon 2 must be successfully navigated before adversaries ascend in this technological (and societal) space and limit the advances.

The challenges, solutions and risks assigned to the map exercise were instantiated through the use of an exploratory vignette, a plausible situational narrative supplied to the four working groups to help formulate issues (challenges, solutions, risks) in near, mid or far-term time horizons, associated with the map.

The outcome of the generative process resulted in:

- **23 Challenges or Problems** deemed essential to undertake in autonomy research;
- **25 Projects** or **Technology Solutions** addressing the user's needs in the future situation or the challenges;
- **26 Risks, Vulnerabilities, Uncertainties or Failure points.**

3.1.2 Theme Construction (Category Clustering). Detailed contributions within the Three Horizons were organized into 11 affinity clusters or themes.

1. *Sensing (Service), Agility, Flexibility, OSDA*
2. *Hubris, Hopeful-yet-Skeptical Artificial Consciousness*
3. *Theory of Cognition, Theory of Autonomy, Social Radar, Meaning Making Re: Behavior*
4. *Human-Computer Interaction, Mistrust*
5. *Taxonomies*
6. *Cascading Effects, "Black Swan"/"Unexpected Twist"*
7. *ID, Sensor Exploitation, Intent, Automation, Current Attempts*
8. *Quantification, Characterization, Unknown Surprise*
9. *Substrate of Autonomy*
10. *Cognitive Computing*
11. *Stovepipes, Cultural Impediments, Non-Materiel Solutions in CONOPS, DOTMLPF-P, Acquisition Policy*

Relevant stakeholders associated with the problem areas were generated for their anticipated interests in the near, mid and far-term horizons. Stakeholder discovery was carried forward over the course of the project, and a stakeholder analysis and table is provided in the Appendices.

In-depth interviews were held with six of the critical contributors to the steering group (Rogers, Westerkamp, Fenstermacher, Overholt, Kearns, and Velten). The summary

published in the Discovery final report provides telling insight with continuing relevance to future Autonomy planning and programs. Several key issues were raised in interviews relevant to the workshops, but these issues have not yet been addressed. The following are direct quotes within this context:

- *The long term challenge in Autonomy is in providing a more contextualized understanding which necessarily requires integration of functions currently separated by culture and geography and in competition with each other resource-wise.*
- *The Autonomy challenge is to provide a more contextualized understanding to guide the collection and interpretation of information by ISR analysts. The focus previously was largely on the Identification and detection of targets. Now the challenge is to not only detect and identify targets but also to understand threat and motivation. The computer by itself cannot reason about threat.*
- *The US will lose our technology advantage because everyone will be able to get the data and commercially available processing. The necessary military advantage lies in this area – integration and improved decision making by humans and Sensing as a Service.*
- *Google is spending twice as much on R&D as the US Air Force - but even their solution is relatively fragile. We're not along as far as the public thinks - what is there is a slick engineering demonstration.*
- *Every division wants a piece of autonomy to look good to the Pentagon (i.e., it will have to be a collaborative organizational solution for everyone to win).*
- *We are facing organizational issues – we cannot get the divisions to attack EW, ISR, CID and Strike because together they are competing for resources. That's in one directorate. But it is a problem also across multiple directorates. Organizationally, it may have made sense 25 years ago. For example, there should not be a Sensors Directorate; we should press on Sensing.*
- *One of the challenges is it needs to be cross directorate. But the money is not integrated. PCPAD-x on the surface is three different directorates but they are not collaborating. This was an integration project – not even research. The pieces are still developed very separately, in isolation. Each develops what they think is needed by the customer then they try to put it together. Geographic separation is a big deal, separate sub-cultures. Addressing the barriers to collaboration is important here.*

3.2 Summary of Discovery Stage

The following activities comprised the Discovery workshop (*AFRL/RY Autonomy in ISR*). A publicly-cleared report was released June 2, 2015.

1. ***Creating exploratory scenarios*** *for situations of autonomy factors over Near, Mid, Far, and "Other."*

2. ***Generating Challenges by Red Teaming.*** *Participants critiqued and appended the concepts associated with scenarios, contributing Challenges, Projects/Solutions, and Vulnerabilities.*
3. ***Three Horizons*** *mapping of issues across Near, Mid, and Far-time horizons.*
4. ***Identify stakeholders*** *by time horizon and predominant issues.*
5. ***Clustering*** *issues by similarity to produce categories/themes.*
6. ***Build narratives*** *across themes that bridge themes and drivers.*

The Discovery report analyzed the contributions and presented findings. Several general insights were reported. A number of significant risks and challenges considered serious across the directorates and disciplines were revealed, and these should be positioned with a higher priority than project-related issues, since their disposition affects all autonomy projects and yet specific risks may be overlooked due to their not being owned by any single project or manager.

One of the insights of highest mutual concern was that of *organizational collaboration on the right issues and questions*. Organizational issues are raised in each of these workshops, but then are suppressed in discussion because they are not amenable to comparison or inclusion with the primarily technical issues. We had no organizational expert participants, as there were experts for each technological or human factors challenge, so these issues could be considered underrepresented.

The issue signified here as “Stovepipes” was stated as a single challenge, within its own category and apparently unrelated to other challenges. While that might have been an outlier in the arrangement of issues in clustering, we should note that nearly every interview participant voiced a concern for better collaboration within AFRL. As a prevalent thread across the interviews, a sincere concern was raised for appropriate organization of staff, disciplines, internal and external members, and aligned mandates. While this is an appropriate problem for Collaborative Foresight, it was not seen an immediate focus. Rather, the potential for collaboration was seen as resulting from the integrated planning approach.

Two areas that emerge from collaborative discussions in Discovery that were not specifically indicated in interviews (as we found some, but relatively little support in the interview text) include the following:

- ***Pick-up Games*** *(and to some extent even the closely related Black Swan events / Unexpected Query, as indicated by Steve Rogers); and*
- ***Don’t Understand Boundary Conditions*** *(which was not described as such in interviews, but may exist “between the lines”).*

Either of these might be reframed as triggering questions for a Collaborative Foresight series. Both deal with deeply rooted risk vulnerabilities, both are internally manageable responses to external problem configurations, and both risks have multiple meanings across disciplines that might yield significant benefits if their relationships were better understood.

All three of these deeply rooted yet "unexpected" problem areas could be developed as sources for collaborative inquiry in SDD. One approach we might recommend for pursuit of these issues would be to conduct a steering group SDD workshop relatively soon to develop a group understanding of these issues in more depth, as a problem system of inter-related risks. A leading candidate for the driver in this inquiry is the theory and model of the Pick-Up Game, especially for A2AD and emergent, multi-player geopolitical situations. The Pick-Up Game represents a critical uncertainty and vulnerability for the users, e.g., Air Control Center (ACC), Intelligence Community (IC) Analysts, and necessitates a meaningful response from AFRL. The triggering question might be similar to "What are the risk factors and barriers to addressing the problem of the unexpected query in Pick-Up Games, in the context of Autonomy research and capabilities?" As this triggering question would address unexpected queries and boundary conditions, it would also be likely to re-incorporate the "stovepipes" issue.

3.3 Collaborative Foresight Workshop

The first Collaborative Foresight[1] Workshop was held December 15, 2014 with 21 participants from across AFRL directorates and AFIT. Structured Dialogic Design[SM] (SDD) was employed as the workshop method, a system of interactive planning employed in past AFRL and government engagements and documented by the 2014 *Technology Forecasting and Social Change* article authored by Dr. Weigand and DDI(2).

The triggering question (focus problem) chosen for the session was based on the fusion of central issues drawn from thematic analysis of the Discovery workshop contributions:

"What challenges ought AFRL lead for autonomous response to the unexpected in "pick-up games" enabling effective Strike, EW/Cyber and ISR?"

One value of the SDD process is the succinct presentation of primary, direct findings of the workshop in an influence map generated from Interpretive Structural Modeling (ISM) software used in the SDD voting method. ISM presents an acyclic directed graph representation of the systemic relationships among the highest-priority challenges (highest voted) selected for consideration. The influence map represents the group's consensus voting on the strength of relationship of challenges to each other, as shown by their leverage as depicted in Figure 3. Additional documentation of outputs are provided in Appendix 6.

[1] Structured Dialogic Design is a registered service mark (SM) of the Institute for 21st Century Agoras, and is an established methodology for facilitating multi-stakeholder engagements for achieving consensus for strategic planning in complex system domains.

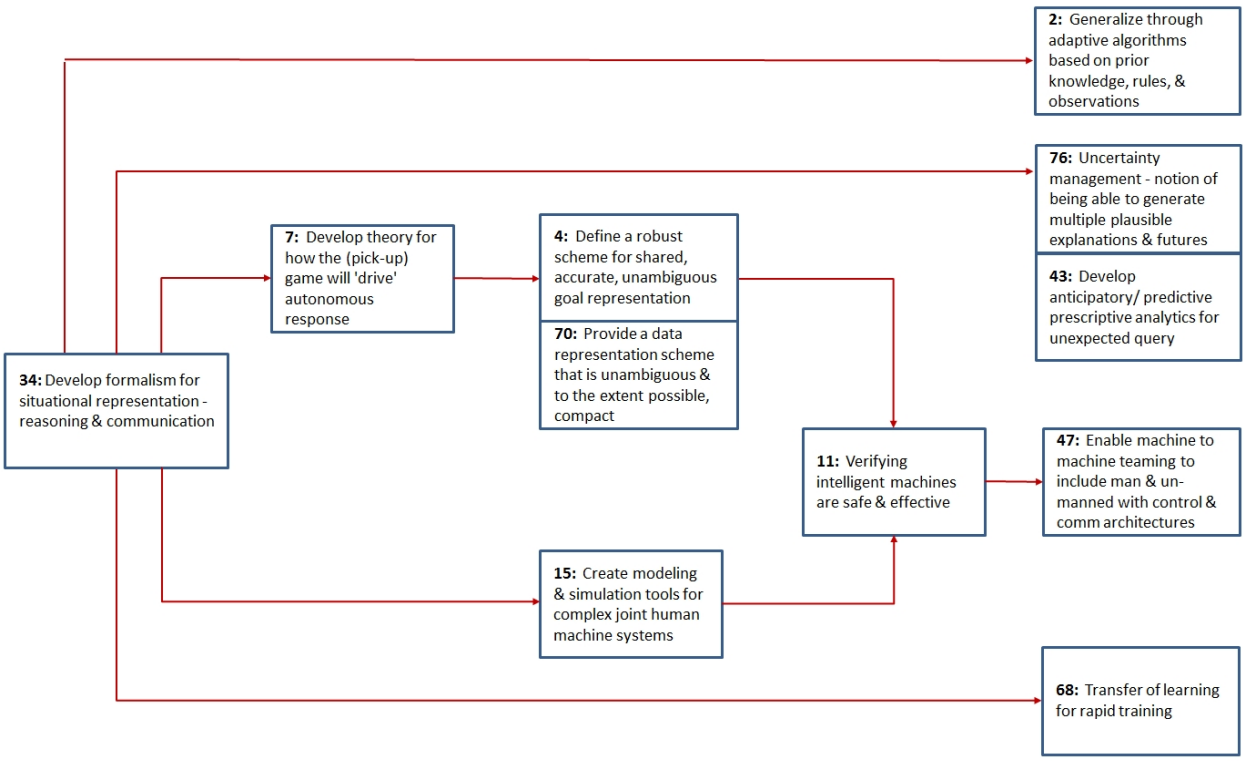

Figure 3. Influence Map from Autonomy Discovery SDD Session
(X significantly influences -> Y -> Z)

The influence map is read left to right, whereby the left-most challenges suggest the most influential proposals with leverage on the right-most challenges. The challenges furthest to the right can be read as the significant desired outcomes of different stakeholders. A total of 76 challenge statements were formulated by the participants in response to the triggering question, and the 11 in the influence map were those selected based on their being voted highly for inclusion (with 2 or more votes). We can say that progress on C34 causally influences challenges across the 4 other levels of the map (based on its reachability score), so progress on C34 advances the objectives of the 5 right-most challenges.

The influence map is a representative snapshot of the key challenges as viewed by this particular group of participants based upon their understanding of the issues as of December 15, 2014. All challenges which received three or more votes are included in the diagram as well as a few with two votes. (See following Workshop Summary section for the list of workshop participants).

The essential meanings of the influence map are developed in the workshop by dialogue among the stakeholders. At the end of the workshop, three participants presented narratives of their view of the map of challenges, and the report presents their findings and interprets the issues represented. We note that the “deepest drivers” of the challenge network are well-represented by AFRL/RY research agendas:

> **C34:** Develop formalism for situation representation - reasoning & communication (deepest, links to Level 2)
> **C7:** Develop theory for how the (pick-up) game will 'drive' autonomous response (links to Level 3)

The most *influenced* challenge in the center pathway is a well-known goal of QuEST:

C47: Enable machine to machine teaming to include man & un-manned with control & comm architectures

Challenge 34 was considered significant enough that the continuing series of SDD workshops was planned to further develop the range (disciplinary variety) of scientific knowledge and research options associated with its exploitation. A composite definition was constructed in analysis to incorporate all the relevant qualities indicated for C34:

> Developing a Formalism for Situation Representation, Reasoning & Communication. It should be Agnostic, Interdisciplinary, Flexible, Robust, Shared/Common, Unambiguous, Accurate, Compact and Intermediate to Diverse Data Sources and Modalities.

The author of the challenge, Jared Culbertson, described its meaning in the session as:

> *"So 34 was intentionally meant to mean **any level of representation**. So when I talk about situations I don't just mean it high level but all through the layers of abstraction and across all scales. I really mean anything in the agent's representation that matters. I think it's important to have a homogeneous representation to some degree that explicitly deals with the problem of going from the low-level to the high-level stuff."*

As C34 was found as a single deep driver and influential across the entire ISM influence map, further dialogue and contribution to the map was encouraged at the conclusion of the session. John Racquet, the author of C7, suggested that challenges 7 and 34 could be combined as a cycle, mutually informing one other as a "theory of mind" of situations. Understanding of the dynamics and meanings of the "zero-day pickup game" was seen as a critical driver to represent the meaningful knowledge of a *situation*.

An account of the workshop findings (with supporting details) is provided in Appendix 6.

3.4 Engagements Addressing AFRL Autonomy Challenges

The DDI plan for AFRL Autonomy Discovery anticipated a series of SDD workshops, organized as multi-day multi-stakeholder workshops for challenge discovery, solution formulation, and action planning.

Planning for two SDD workshops to follow the Autonomy Challenges session began immediately following the delivery of the final report (March 2015) and an Autonomy Workshops Plan was delivered April 15, 2015. Proposed dates for the two follow-on workshops ranged from late August to early December 2015 and a 2016 date for the third session. These dates were deliberately established further into the year, to allow time for participants in the summer studies (and the Autonomy initiative demonstration effort) to complete and when stakeholders were expected to be more accessible. However, the earlier dates proved unworkable and a December 1-2 date range was selected. When this date was also threatened by inaccessibility of participants, DDI arranged a Pilot Workshop to develop the approach to identifying approaches (preliminary solutions) to the critical challenges discovered in the Autonomy Challenges workshop. (Only 2 participants were able to attend the pilot session, from a list of 15.)

3.4.1 Pilot Workshop Findings. The pilot workshop was held December 1, 2015 to develop and evaluate the approach for the planned SDD2 Collaborative Foresight session.

The half-day session was held in lieu of the 2-3 day SDD2 workshop originally proposed for the period. We completed a series of stakeholder interviews and materials preparation, and provided the opportunity for feedback and alignment within the AFRL organization. This developmental pilot workshop covered:

- *SDD2 workshop plan and triggering questions;*
- *Stakeholder analysis and recruiting discussion;*
- *Review of the narrative (science fiction) story The Situation;*
- *SDD2 Triggering Question (TQ) walkthrough; and*
- *Cross-Impact Outcome Map review.*

A central issue for the workshop was the assessment of the Triggering Question with the AFRL/RY stakeholders to iterate its fit and desirability for SDD2. The TQ under evaluation was purposefully specialized and quite detailed, tested for the SDD2 workshop to elicit approaches or "solutions:"

What AFRL approaches might be feasible in the far term that address the challenges of situation representation for autonomous response to "pick-up games" creating a common technical trajectory toward the fusion of ISR, EW/Cyber & CID?

The TQ follows a canonical form: (Question type – What) (Object output type – Approaches) (Timeframe – Far Term) (Problem context – That address challenges from SDD1 …). It also included the end product or desired outcome from the two workshops, the *common technical trajectory*. The "trajectory" can be considered the precursor to the ultimate outcome of a *unified technical vision* and an R&D project/investment roadmap. A proposed methodology for constructing the trajectory as a systemic model was presented and discussed, shown in Figure 6, and follows in Chapter 6.

Following the Pilot workshop, DDI prepared interim reports and developed analyses for:

- *Narrative Future Document "The Situation" version 1.0 (3)*
- *SDD2 Stakeholder Matrix (XLS file)*
- *Detailed SDD2 agenda and plan*
- *Analysis of MITRE "Grabowski" Report for Challenges, Solutions and Risks (4)*
- *Analysis of Endsley's Autonomous Horizons Report (5)*
- *Category mapping of key categories (selected from Endsley & Grabowski reports)*
- *Cross-Impact Outcome Map v.5 for review and discussion*
- *Initial research literature scoping review and glossary*
- *Development of SDD promotion / rollout materials: PPT deck and XLS format*
- *Planning and coordination of SDD Pilot workshop*

The Pilot session usefully demonstrated how the TQ might elicit responses in the SDD2 workshop based on the current autonomy research contexts within the AFRL organization. A total of 22 statements were arranged in a group-deliberated influence pattern such as shown in Figure 4.

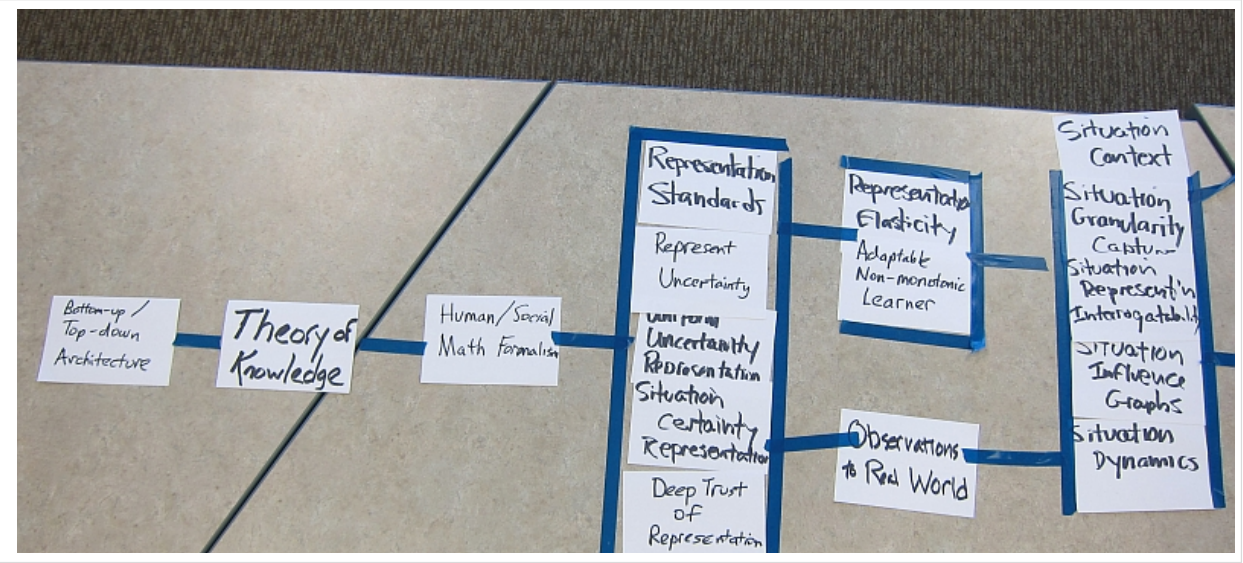

Figure 4. Influence Map Constructed in Pilot Workshop

The two participants and Kirk Weigand, the organizer, constructed and arranged the responses to the triggering question as a hand-sorted influence map following the logic of "progress on A yields progress on B." The most highly leveraged approaches were "Bottom-up, Top-down Architecture" and "Theory of Mind," linking up the influence scale to "Human/Social Math Formalism" (similar to C34).

There were five sets of mutual groups (cycles) discerned in the influence pattern, which reveal that many of these statements were closely related to known issues or technological requirements. The overall influence pattern suggested that three continuing deep drivers, as shown in the three left-most "Architecture, Theory, and Formalism" have been repeatedly recurring across sessions and analyses.

The majority of these statements were framed as requirements, as statements of desired capability or a level of performance as a benchmark for planned future outcomes. We find a structure of categories that might define the next generation situation representation formalism. Therefore the Pilot session was found useful to scope and design the SDD2 Workshop, which was subsequently planned for late April 2016.

4. 0 Results and Discussion

The following chapter presents two sections that help readers gain a current understanding of issues associated with Autonomy from interview and literature summaries prepared during the research phases.

4.1 Interview Summary

Over the course of the project, three rounds of interviews were conducted with different AFRL experts in the Sensors and Human Effectiveness directorates. Initial interviews were held with Dr. Rogers and others before the September 2014 Discovery workshop. Several in-depth interviews were also held to evaluate the formative triggering question for the first Collaborative Foresight workshop. A third round of focused interviews was also held as part of planning for the planned 2016 workshops. An interview series was held September 2015 to develop the appropriate focus and concepts for the two Collaborative Foresight workshops and evaluate the triggering question (as tested in the Pilot workshop). An edited representation of comments are presented from each expert.

Steve Rogers
RY / RI, QUEST LEAD AND PROJECT SPONSOR

Steve Rogers, lead of the QUalia Exploitation of Sensing Technology (QuEST) initiative, was the project sponsor over the period of the project. Several interviews and a number of informal discussions were held over the period, with the following summary representing the most recent interview from September 27, 2015. The relationship of QuEST research and technology issues to Autonomy Discovery was developed in the first Discovery workshop in 2014, and in the models presented further in this report.

- *The original intent of this effort (Autonomy Discovery) was to help chart a direction for Autonomy.*
- *We are trying to catch the early tail of the Third Horizon. The other efforts are driving toward a demonstration in the earlier horizons.*
- *At the highest levels there is a recognition of the need to do what we are trying to do – how to take multiple mission threads and treat them in a common way to achieve better mission effects.*
- *Sensing as a Service – was for that but it was an A2 document and A2 can't tell A3 what to do. What happens when we don't have different platforms with distinct missions – it won't be platform centric – it will be effects-centric. The Combat Cloud will determine – starts with intent of Sensing as a Service but broadened to all effects.*
- *We should still focus on Strike, EW/Cyber, ISR, any of these capabilities spaces. Two numbered Air Forces have to figure this out. The focus, take this view of the Combat Cloud – how do you achieve effects when you do not own organically the way to achieve those effects?*
- *But don't include targeting (Strike, Combat ID). The DoD Regulation 3000.XX on Autonomy and Weapon Systems specifically prevents us from going down the Strike path. Maybe it should not be called Combat ID.*

- *My view of (deep challenge) #34. Talking to Larry Barsalou at Emory, the fundamental unit of cognition is "situations." Add on to that a representation for System 1 (instinctive) and System 2 (deliberative), I'm more and more convinced that they share a common framework.*
- *We populate a representation based on concepts not on situations. Jared may believe that we can build a representation in a bottom-up approach. But I think that there may be just as much top-down approach.*
- *Theory of Mind means if there are two agents, one represents the other's representation of the environment. The clinical approach example of two puppets and the ball for testing autism (one puppet leaves the scene and the ball is placed in another hidden location, and the autistic child believes the puppet will "believe" the ball to be in this location they hadn't seen).*
- *(Rather than) using the phrase Theory of Mind, Challenge #34 says to me we need a theory of situations and a formalism for manipulating them (the Barsalou approach). When you say formalism – give me an approach to generation / manipulation of the situation to achieve some purpose. If we are going to do the communication piece – that is a whole other thing.*
- *What's to the left of that? Category-theoretic pieces. Thought Vector Space representation of ideas. Not situation awareness representations – that is the one path forward idea which I believe is flawed. Once you have the Situation Representation (we don't have a definition for what that means) maybe that is something to the left of #34.*

Laurie Fenstermacher
AFRL HUMAN EFFECTIVENESS DIRECTORATE 711 HPW/RHXM

Laurie's interview clearly makes the case for the need for situational representation to integrate the human intelligence and decision capability necessary for meaning making of an emergent threat or situation. She develops the requirement for a tightly-coupled ISR function, first within the Lab and the PED/ISR function, but then to build more collaborative problem-focused organizational units that can shift in response to real-world demands. She points to significant risks incurred from the "mirroring" in future field operations and in the Lab today. She raises concern for extrapolating from "the way things have always been done" to a dynamic and complex environment unlike any in the past that was designed for. The organization risks introducing its own inability to organize tightly coupled teams into the technology teaming necessary in the 2030 future frame. Today's compartmentalized experts will become a hindrance to future ISR capabilities if this persists, as the gap between human realities and technology drivers will continue to expand.

- *We have a huge gap - the notion of extrapolating from what we've done in the past – "Since I must label things, then get a better label." The ID piece (was the goal). When we had environments where it was clear there was a threat, the way it is instantiated, and where the threat was.*
- *But in recent decades, with increasing complexity now it is people and people in amidst other people, people that behave and we have to determine if their*

behavior is indicative of threat. We add more automation, computing technology, and more overlapping, higher "clutter" or the change from moment to moment, high confuser, low S / N, Low Signal to Noise. Now the computer must be a different kind of partner. The kinds of things you give your proxy to are way more limited, the human must be way more involved and have contextualized understanding.

- *One of the most fundamental things we need to change - AF attitude is "we are flying airplanes" – and not on the ground - let the Army worry about the social cultural thing. In the Army - every soldier needs contextual understanding. Not all people collecting information needs to be "deep SMEs" but we do need understanding, not just certain people. There is such a big gap right now - one of our biggest issues with analysis is in the meaning making piece - it falls apart because of mirroring, seeing only what we know and are biased to see in the analysis.*
- *In the Sensors world, we have compartmentalized experts that can't share with each other or with those who understand the human side. For (tactical) intel collection and interpretation, where we must make fast decisions - the compartmentalized guy is not going to be part of the decisions.*
- *There's a huge gap between the strategic/operations timeframe and the tactical. We're not just facing one threat, but dozens, at once. But NASIC analysts have only two teams, plus some academics – how do you rebalance the tasking of these intelligence tasks?*
- *Now there is a huge gap. The big thing of the AF is ISR, from Phase 0 to conflict.*
- *The lab is organized around it being a slower problem - but for example, information, sensors and human effectiveness should be collocated. We need to reorganize to connect the Lab to ISR intel operators to the field …*
- *Things are happening in certain dimensions of our business… we know that collection and analysis of publicly available information (code for Open Source Intel) we know that OSI is hugely important but what we don't have are systematic ways of following, analyzing, interpreting that information.*
- *We need ways of combining with the other information we are collecting. We are spinning out new capabilities all the time, i.e., new types of Social Media. The Lab should be a "reach-back" capability, for spinning it into the field. The lab and the operators need to be tightly coupled.*
- *Intel and ops need to be tightly coupled – but we (Lab) are massively afraid of organizational change - but in so doing we are limiting our ability to support operations, ops recognizes that we are not responsive.*
- *Right now there are barriers in the way we operate and the way we are structured. But things are not going to get any more predictable.*
- *Autonomy doesn't mean we are handing over decision making to computers. We are generally looking for smarter automation for human decisions.*

- *Typically when they talk about Situation Representation their notion is to build smarts into the automation that starts to make it a better partner for the human but their focus is from the automation perspective.*
- *(C#34) Structured Formalism sounds like they recognize that they need more context, but it does not feel like the dynamic, fluid, teaming with automation. Improving automation is fine but the deep driver has to be something that talks about the team that enables people.*
- *We can't talk about Situational Representation on its own as Threat Detection / Threat ID - it's got to include the human. If you talk about it just as if it is a better algorithm or machine learning I think it would be a mistake.*
- *In development and in Operations there are some people that have these kinds of functions and have to make quick decisions and they cannot do a deep reach-back. But we need to build on the notion of having them more tightly coupled – We have a problem with foveation (narrow focus).*
- *The seams aren't serving us. People will always be involved in decisions.*
- *Being tightly coupled is critical, because otherwise you lose the ability to consider plausible futures.*

Raj Malhotra
AFRL / RYAR

- ***Consider TQ focus**: What are the critical objectives to be satisfied by situation representation for underpinning human-machine teaming in an emergent, pick-up game context in mid-long term future ISR?*
- *If we include non-AF stakeholders, we will be obligated to open up the framing so as not to confuse the multiple domains of EW, cyber, CID within the discussion. Based on my reading of the robotics and autonomy futures literature, it seems clear these separate functions are just stovepipes waiting to dissolve.*
- *Future defense systems with autonomous sensing and collaborative teaming will not be designated by these functional domains. ISR would likely have multiple OODA timeframes.*
- *Cyber-ISR would be the fastest scan of computer-originated attacks on electronic assets, using extremely fast algorithmic scanning. "Instant ISR" might register emerging problems or CID targets, "daily-ISR" might monitor problems and cover agent and vehicle sorties, weekly-ISR might require multi-analyst assessment, and long-ISR monitors nations and cultures.*
- *The OODA loop, as one paradigm, is how humans observe and orient ourselves – that is along the lines of representing a situation in our mind – but the other side of the loop is to decide and act. Deciding and acting is not done in a centralized location – it's done across a collection of assets, sensing agents in contested environments in which they may not be able to communicate. Even if they all have a sense of the situation there is still an aspect of how to communicate, decide, and act. The idea of distributed information sharing.*

- *I think that the Situation Understanding may be located on the agent but then... 0r the understanding might be across the collection of assets, i.e. the DARPA CODE program. Collaborative Operations in Denied Environments. There is no one single place you can point to on a computer in which you can say this is the situation right here. I think a lot of people would find that objectionable.*
- *The next question – where does it exist? Probably on board the agent. Potentially back behind the lines where they are planning and integrating information. At any one point in time if they don't have the same, currently what we are relying on is an agent may have a different understanding, but their ability to communicate is limited to an area, so if they are not too divergent it may not matter much. We got to the point in which we had distributed sensing agents and their view is different – but not in a significant way – the difference is …I am searching in one place and you are searching in another and when I get your info I can update so that the nature of the conflict in pictures may not be very big.*
- *My mental picture for Autonomous Sensing Systems is the operator is on the terminal interacting with systems, arbitrating across system goals and trying to decide tasks for sensing, that is what the automation does. We don't always understand the Human end – that is why we are working with RH – human machine teaming to allow an operator sit on the loop of higher end mission goals.*
- *The Situated Decision Process is to push it to the lowest level in which there is context to make a decision. Information comes back and he ends up saying "that is a hazardous area, you are not going to find anything over there" - this guy has cognitive overload – setting up a collection and too involved in that. It's not one operator, it's in an unmanned system with 20 operators.*

Jared Culbertson
AFRL / RYAT

- *When I talk about SR it is with respect to a particular agent and a particular task, it's about the representation they are using to make a decision. There is not a distinction between situation and situational – I tend to use situational simply because it sounds more like an adjective than and noun. It's more of a functional definitions – the structures that an agent is using to make a decision.*
- *Formalisms I think of as, a mathematical model that you could actually implement. There are a lot of models – Endsley's being one of them even though we might disagree on the objective. I would distinguish between model and formalisms, which is something that you could actually implement in a machine, i.e. working with directed graphs.*
- *It's very important if you want some sort of theory to match tasks to teams in which teams include both human and machine – so you would need a way to represent human decision making. What resolution do you need to do that I don't know.*
- *One of the desires for a Situational Representation is that it allows for (implementing models) …. such as Theory of Mind – if I know what the agent is doing then I can communicate better with it. Every machine we interact with*

understands us at some level but we would like to make that more complex – to collaborate with a human in a more refined way.

- *IF it's possible to focus on the unexpected piece and the dynamic piece. Those are the characteristics of systems that are not adequately addressed in current approaches. Changes with respect to changes in the environment and degradation of sensors and dealing with unexpected things.*
- *Understanding human decision making and human modeling are good, but from an RY perspective we care about that but also building better machines and better man-machine teams to do specific tasks – we need to focus on implementable formalisms and real algorithms that can be implemented in machines.*
- *(What do you need to validate now in the theory in order to propel us forward?) This is a good point. The benchmarks are not really there for this type of problem – how do you know if you really achieve something?*
- *I don't mean this as critique but the approach in the community is simple (toy-like) examples – we don't have a set of problems or description of problems that say if we could solve this we would be making progress.*

Robert Patterson
AFRL HUMAN EFFECTIVENESS DIRECTORATE 711 HPW/RHXM

- *There are a number of ideas in the literature, and some of them conflict with one another. Nonetheless, there are still some key ideas on human decision making that one can glean from the literature that can be expanded and tested. This includes new knowledge in cognitive science.*
- *What masks and obscures it is a reliance on models of human performance, but none of those models capture the richness of actual decision behavior. For example – the (Daniel Kahneman) model is flawed, it captures System 1 and intuitive cognitions. But advancing human-machine systems is premature.*
- *(AF science advisor) Gary Klein's literature is on target but he does not go far enough – Situational Pattern Synthesis (not just recognition).*
- *(Philosopher Charles Sanders) Peirce's interpretation of the meaning of a situation is as a sign for something else – a derived object. That interpretation as a sign is a cognitive synthesis process (what I am arguing) – it's not a sign drawn from memory – it is an abductive process.*
- *There is a huge thing to the left of the influence map. It's presupposing we understand how people actually reason. All we have are descriptions, not actual mechanisms.*
- *We need to understand the situation crux of everything we are talking about. Without understanding a situation and how humans make meaning with it.*

4.2 Literature Scan of Current Issues

The following section presents an annotated bibliography of concise references to relevant autonomy issues from across the current literature.

4.2.1 Factors & Mandates from Leadership Guidance

The following factors and mandates are what the authors are aware of from DoD and AF guidance that seems relevant to autonomy research and development practices and/or drives the sciences and technologies that may impact mid-to-far term demonstration of operationally-revolutionary autonomy.

Air Force Future Operating Concept

The Air Force Future Operating Concept (6), presents a comprehensive, far-term future-located (2035) concept of operations situating autonomous, semi-autonomous and mixed-capability assets to be deployed for AF, joint or multinational objectives. The mission functions of the 2035 Conops are defined as Multi-Domain C2, Adaptive Domain Control, Global Integrated ISR, Rapid Global Mobility, and Global Precision Strike, orgnanized within a framework of operational agility.

> *AF forces operate with a balanced capability mix composed of manned, remotely operated, semiautonomous, and autonomous air, space, and cyberspace assets, including sophisticated systems to achieve adaptive domain control against advanced adversaries and lower-capability systems for actions against a reduced or less-capable array of threats. AF forces present these assets in various combinations and proportions according to mission needs.*
>
> *(Among the dozen implications) A more transparent, networked infrastructure that integrates ubiquitous sensors, automated systems, information nodes/connections, and human cognition in a secure, reliable, resilient, and high-capacity global information architecture able to withstand breaks in connectivity while still allowing users to collaborate with other operators to maintain localized situational awareness.*

The clear direction of the future concept of operations is that autonomous and intelligent systems will be integrated into operations as trusted team members with human guidance and human planning, and that there are significant challenges ahead to develop and integrate these systems into new operating regimes.

Defense Science Board 2015 Autonomy Summer Study

The Terms of Reference letter[2] calls for investigating the following purposes and range of autonomy issues across Air Force projects:

> *"The purpose of this study is to identify the science, engineering, and policy problems that must be solved to permit greater operational use of autonomy across all warfighting domains. The study will assess opportunities for DoD to enhance mission efficiency, shrink life-cycle costs, and reduce loss of life through the use of autonomy. Emphasis will be given to exploration of the bounds-both technological and social-that limit the use of autonomy across a wide range of military operations. The study will ask questions such as: What activities cannot*

[2] Terms of Reference, *Defense Science Board 2015 Summer Study on Autonomy*, 17 Nov 2014.

today be performed autonomously? When is human intervention required? What limits the use of autonomy? How might we overcome those limits and expand the use of autonomy in the near term as well as over the next 2 decades?"

From this document, we conclude that, like the Defense Science Board 2012 Autonomy report, guidance is given to exploit technology that may currently be possible but out of reach due to a combination of social and technological interplaying factors. As we review the literature and internal expert interviews, we did not discover that these questions have been addressed adequately. The answers to human intervention and social boundaries should be developed within a plausible future-oriented presentation of possible technology adaptations and outcomes, not in abstract rules and conditions which may never be thoughtfully considered. An interdisciplinary and cross-functional collaboration is therefore required to reveal and solve these complex issues.

Air Force "Bending the Cost Curve"

The Air Force is calling for ways to revolutionize longer-term autonomy through advancing innovation processes through collaboration. Secretary of the Air Force Deborah Lee James[3] presented these proposals in a well-known speech, "Bending the Cost Curve," advocating enhanced dialogue and partnership with industry and academia.

AFRL Commander's Intent Letter

From the AFRL Commander's Intent[4] guidance, we see a continued call for "Game Changing" autonomy and conclude from Discovery and the Collaborative Foresight workshop (SDD1) that Situation Representation formalisms must achieve a breakthrough to accomplish this desired outcome.

AFRL Autonomy Strategy 2013

General Maciello's AFRL Autonomy Strategy (7) resonates with the results of Autonomy Discovery workshops with a vision for autonomy that can be best represented as:

"Intelligent machines seamlessly integrated with humans – maximizing mission performance in complex and contested environments"

Yet the strategy does not yet develop a connection to Situation Representation and the human aspects of autonomy necessary for trusted teaming and cooperative training.

DSB 2012 Autonomy Report

The Defense Science Board Report (8) provides a deep analysis of the human and technical aspects of autonomy. From this source, we quote the DSB findings:

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[3] James, Deborah. (2013). *Bending the Cost Curve with Debbie James, Secretary of the Air Force*. Presentation to the Atlantic Council. Video accessed May 31, 2016 at http://youtube.com/watch?v=dVkdkQxjZe0

[4] AFRL Commander's Intent Letter, 29 Oct 2014.

"To address the issues that are limiting more extensive use of autonomy in DoD systems, the Task Force recommends a crosscutting approach that includes the following key elements:

- *The DoD should embrace a three-facet (cognitive echelon, mission timelines and human-machine system trade spaces) autonomous systems framework to assist program managers in shaping technology programs, as well as to assist acquisition officers and developers in making key decisions related to the design and evaluation of future systems.*
- *The Assistant Secretary of Defense for Research and Engineering (ASD(R&E)) should work with the Military Services to establish a coordinated science and technology (S&T) program guided by feedback from operational experience and evolving mission requirements.*
- *The Undersecretary of Defense for Acquisition, Technology and Logistics should create developmental and operational test and evaluation (OT&E) techniques that focus on the unique challenges of autonomy (to include developing operational training techniques that explicitly build trust in autonomous systems).*
- *The Joint Staff and the Services should improve the requirements process to develop a mission capability pull for autonomous systems to identify missed opportunities and desirable future system capabilities."*

We conclude that Test and Evaluation, Operations and diverse research experiences must be tied together in a mid-to-far term scenario that represents the dynamics of future missions.

OSD Autonomy RFI

The Office of the Secretary of Defense (OSD) publicized an open RFI[5] in late 2013 for industry and academia to propose longer-term breakthrough solutions for autonomy, cybersecurity, and data research analysis. The 2013 Autonomy Research Pilot Initiative *Catalyzing Collaboration and Communication for Autonomy* encompassed two AFRL projects, *Autonomy for Adaptive Collaborative Sensing* and *A Privileged Sensing Network-Revolutionizing Human-Autonomy Integration*.

NSF National Robotics Initiative

The National Science Foundation represented Pasteur's Quadrant to frame the potential research directions of the National Robotics Initiative.

We believe that autonomy-related R&D can be framed in revolutionary terms, yet consistently with current scientific support and applications. The long-term research essentially belongs in *Pasteur's Quadrant*, the application of new fundamental research aimed at critical problem-solving. Figure 5 shows the standard model of Pasteur's Quadrant (9) as a 2x2 matrix categorizing research applicability and form of knowledge.

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[5] DoD Research and Engineering Enterprise. (2013). *Autonomy Research Pilot Initiative Web Feature*. Retrieved June 1, 2016 from http://www.acq.osd.mil/chieftechnologist/arpi.html

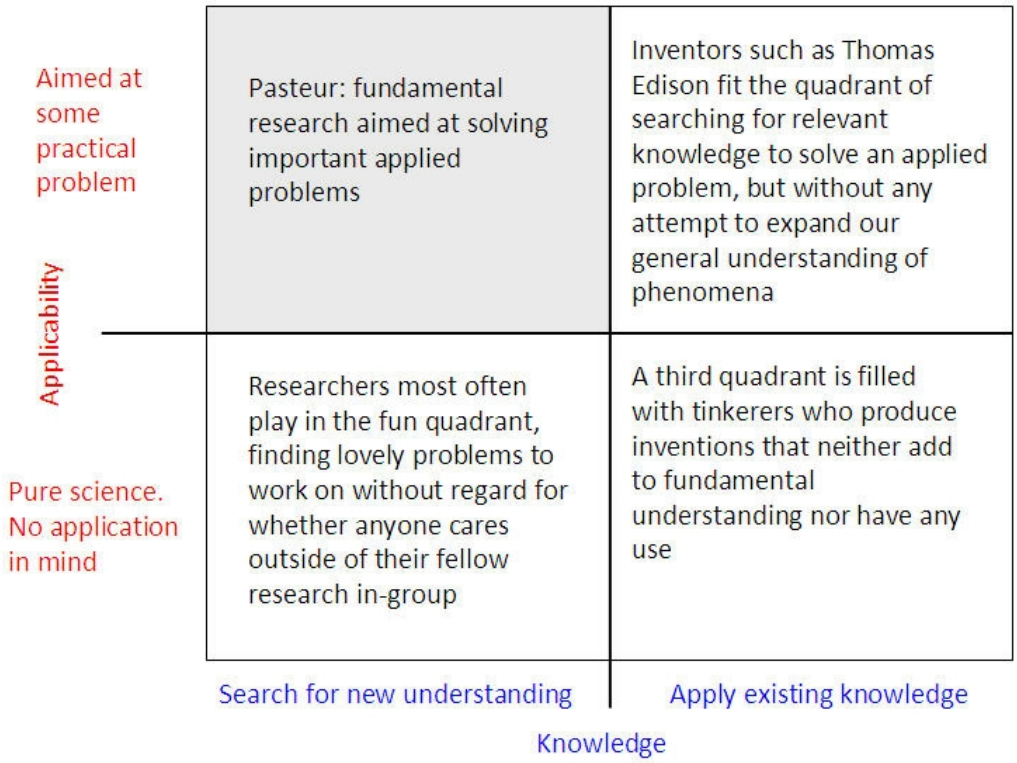

Figure 5. Pasteur's Quadrant (Instone, 2010)

QuEST Objectives

An observation we propose from participating in the QuEST (QUalia Exploitation of Sensing Technology) research group is that the goal of a revolutionary mid-term demonstration may only be achieved through future-driven innovation. A long-term view is indicated by the revolutionary concepts of QuEST and its objectives that far surpass current engineering capabilities.

- *QuEST is an innovative approach to autonomy that improves decision quality over a wide range of stimuli (unexpected queries) by providing computer-based decision aids that are engineered with both intuition and the ability to do deliberative (artificial conscious) thinking.*
- *QuEST further provides a mathematical framework to understand what can be known by a group of people and their computer-based decision aids about situations to facilitate prediction of when more people (different training) or computer aids are necessary to make a particular decision.*

- *QuEST is proposed as the predominant model for decision allocation in autonomous sensing systems, based on a deliberative approach to situation representation.*

A far-horizon futures orientation is one of the desired outcomes from the strategic foresight contributions of the current efforts, including the workshops and future narrative. This perspective requires research and development planning to reject conventional assumptions regarding a linear accumulation of knowledge and prototypes in science, research and development (represented by 6.1, 6.2, 6.3 and 6.4 funding types). Linear extrapolation from current capabilities will encounter two significant barriers: 1) The inability to identify and leverage emerging knowledge and technologies from non-AFRL quarters that might offer an early advantage (the not-invented-here syndrome) and 2) the accumulation of material, reputational and psychic costs invested in current programs and solutions that prohibit discarding unproductive directions when other solutions might be presented (strategic path dependency).

There are significant precedents in industry and literature for an organized approach to radical innovation (10) which can be framed by Pasteur's quadrant: Basic research with high applicability to the operator. A proposed "Pasteurian" innovation approach might be to develop a demonstration of situation representation for R&D researchers, as customers of the system instead of warfighters (as such as demonstration would not yet be field-ready). This may stimulate scaffolding of human-machine autonomy while instrumenting the demonstration to promote longer-term advanced research agendas.

4.3 Recommended Synthesis of Guidance

Given that emerging leadership guidance may substantially alter the context of factors driving autonomy R&D and S&T, we provisionally submitted a recommended synthesis of findings, driving our selection of key goals for mid-to-far term autonomy. These long-range goals in turn drive our recommended options for a follow-on workshop, which is already funded this year by RYW and RYA. Conducting the workshop as recommended in the Executive Summary will reveal key near-term research and/or policy actions that could significantly enable mid-to-far term achievement of key autonomy goals according to available autonomy guidance.

4.4 Discussion

The Autonomy Collaborative is investigating complex, unresolved scientific challenges that pose barriers to AFRL future outcomes and that generally have no direct resolution in near term actions. The purpose of the Collaborative Foresight approach is to identify the most productive research issues that could, if identified and considered by collaboration across directorates and external stakeholders, lead to significant R&D productivity and effectiveness, especially for longer-term challenge proposals. There are several recommended next steps that could offer value to AFRL directorates and stakeholders.

4.4.1 Deeper, Non-Technical Challenges

In investigating challenges in Autonomy for the Far Term there was a tendency for people to focus on technical challenges in the context of group settings. While there

were organizational and cultural challenges put forth in group settings, discussion of these were more fervent in interviews. As a result there is an inherent bias against surfacing their importance through evaluative mechanisms in the group settings. Another reason for this bias is that in group work we tend to focus on questions of interest to ALL participants while the issues that concern a small number of stakeholders tend to remain underdeveloped. We seek to adjust this bias in this section by calling attention to several types of challenges which seem deeper than the system of challenges presented above. These themes have especially been reiterated in interviews as we sought to surface a sense of deeper problems.

These issues include:

- ***The absence of insight of social science*** *informing a sociocultural model of agent-based situation representation. (Interviews following up on Challenge 34's call for a formalism for agent-based situation representation reveal that no progress is seen toward a substantive model of human representation in situational reasoning).*
- ***The lack of cultural intelligence*** *informing agent representations and decision making with human-autonomous systems (Raised in Discovery, issues of cultural ignorance or lack of a cultural model can show up in mirroring, misinterpretations, or hubris and lead to poor tactical actions or potentially significant human destruction).*
- ***Organizational management barriers*** *to R&D innovation (The inclusion of "stovepipes" and other barriers to collaboration are persistent, yet these are unpopular topics within discourse, as the assembled group has no mandate for action in management).*
- ***Ethical concerns for future autonomy design*** *and applications ("building in morals" is probably an engineering view, but this is much farther reaching and needs to be discussed as a policy driver).*

4.4.2 Human-Centered Autonomy

During the course of the Autonomy Discovery project, from 2014 – 2016, we saw significant advancement in thought leadership across the armed forces. By late 2015 Deputy Secretary of Defense Robert Work, recently CEO of the Center for New American Security (CNAS), widely shared presentations of a strong view toward human-centered autonomy. With co-author Paul Scharre (11) at CNAS, Deputy Secretary Work had previously promoted a platform of "ethical autonomy" and a clear program and strategy for human decision making within autonomous distributed services. While his influence may arrive a little too late to influence many AFRL programs already in progress that assume a stronger role for full-autonomy, the clear strategy espoused by Work before his appointment by the president, now carried into the DoD, defines a significant opportunity for collaborations with a wider range of external experts and stakeholders than originally envisioned in the Autonomy Discovery project.

However, as typical in technology-driven research domains in AFRL, human factors research lags. Platforms and demonstrations must be robust enough to place and evaluate humans-in-the-loop. Human-centered autonomy has not been developed conceptually and there is not an adequate proportion of human factors research within the autonomy sphere. For example, issues mentioned in the Discovery workshop

included the risks of human aspects of Autonomy such as “hubris in the research community” and “trust in AI”.

4.4.3 Principles for Engagement

Dialogic Design International has submitted a number of proposals for collaborative foresight workshops as critical organizing venues for internal and external stakeholders in these significant autonomy questions. All of these proposals pivot around common organizing principles that we believe are crucial for mutual development of socio-technological regimes such as autonomous sensing systems.

We believe key principles for further work in Mid-to-Far Term Autonomy are as follows.

- ***Requisite variety of stakeholders*** *(disciplinary perspectives) with respect to the complexity of the multi-disciplinary issues at stake. AFRL participants identified the need to engage over 80 organizations to address the challenges which they identified. This makes it necessary to extend the boundaries of an engagement beyond the sponsoring organization to ensure the satisfaction of knowledge variety. This aspect of the project is impeded by organizational and management barriers mentioned above.*
- ***Continuity of dialogue****. The high bandwidth afforded in face-to-face communication along with a highly structured approach enables a group to cover the scope of issues in a day or two that might otherwise require months of asynchronous communication. However, until staff learn to participate in structured sessions they may inappropriately judge it based on the lower productivity typical of unstructured meetings.*
- ***A future horizon appropriate to the set of challenges****. Conventional meetings lead to under-conceptualizing complex socio-technological problems such as autonomous sensing, especially when oriented to Far-Term disruptive innovations. SDD and other collaborate foresight methodologies are recommended to focus and extend collective thinking toward the Far Term because staff are not used to working on that horizon and to considering how it might affect near-term decisions.*
- ***Narrative construction that enables full stakeholder participation in problem/solution scoping.*** *In both deliverable reports (Discovery and SDD1) we have provided “deliberative narratives.” These are based strictly on the workshop-generated content. The narratives illustrate systemic relationships between the challenges. This principle is consistent with an influential National Research Council report (13) on Persistent Forecasting of Disruptive Technologies where several key contributions relate to the present plan:*

    > *A major concept reinforced by the workshop is the importance of a focus on developing narratives of the human use and impact of technology instead of a focus on specific technologies.*
    >
    > *Narrative is a useful and powerful tool that can augment and contextualize other forecasting tools and approaches. A forecasting system should therefore start by identifying big problems and opportunities and using them to generate alternative scenarios and hypotheses from which relevant technologies can be derived.*

4.4.4 Forming Collaborative Inquiry Groups

A symposium model for the next two workshops would extend the developmental dialogue into both the academic and private sectors. This would allow AFRL to identify key participants and speakers to broaden the sense of Autonomy research and initiative(s). This might position both QuEST and human-centered autonomy perspectives for broader research collaboration and deeper knowledge development.

An exemplary project we might pattern from is the Naval Postgraduate School's Consortium for Robotics and Unmanned Systems Education and Research (CRUSER). The website for the CRUSER consortium[6] indicates their philosophy and approach to an open, innovative research collaboration, described as a “collaborative environment for the advancement of unmanned systems education and research endeavors” and a “Community of Interest for unmanned systems in military and naval operations.” Their mission is stated broadly, as they include a very wide range of modes, interests and disciplines:

CRUSER takes a broad systems and holistic approach to address issues related to naval unmanned systems research and employment, from technical to ethical, and concept generation to experimentation. Manning requirements, human systems integration, information processing, information display, training, logistics, acquisition, development, C2 architectures, legal constraints, levels of autonomy versus mission risk are just a sample of topics for investigation in addition to technical research areas for these systems.

They explicitly reference the “technical to the ethical” in their mission, and as such must take human-centered problems seriously. We might adopt similar language in our future positioning of the concerns addressed and values engaged in AFRL autonomous systems research.

The AFRL Autonomy Discovery collaboration might be developed along these lines by continuing to promote cross-disciplinary discussion in the QuEST meetings and leveraging the proposed Autonomy Brown-Bag informal lunch discussions as a context for continuing exchange and education. The Discovery work developed in this report from the workshops already conducted could be presented and developed as a framework for identifying key relationships between extant R&D projects that require or call for additional collaboration.

The final report proposes the completion of additional SDD workshops that explore the shared territory of situation representation shared among human and computing agents in autonomy teaming. As workshops are opened up from AFRL to external stakeholders, shared research agendas can be developed by coalitions of industry, academic and AFRL researchers similar to that in CRUSER (and with other similar programs).

[6] Consortium for Robotics and Unmanned Systems Education and Research http://my.nps.edu/web/CRUSER/

5.0 Recommendations and Conclusion

5.1 Common Technical Trajectory

One of the most significant opportunities for AFRL is to develop and mobilize the qualitative roadmap conceived by Dr. Steve Rogers as the Common Technical Trajectory. The “Trajectory” was envisioned as a new type of strategic roadmap that might connect the output models of the Dialogic Design workshops to the strategic goals of AFRL autonomy initiatives, which would ultimately show the relevance of autonomy technical challenges to the strategic impact of enabling the Third Offset Deterrence strategy. Figure 6 in the following turn-page presents such a model trajectory as a proposal for its construction and logic, based only on the source information available to the DDI team at the time.

The proposed trajectory connects two well-established methods for collective definition of actions and challenges toward strategic goals: Dialogic Design (14) and Outcome Mapping (15). The left side of the map (blue and white boxes and directed graphs) shows the influence map from the first Dialogic Design workshop (SDD1). Generated by the Interpretive Structural Modeling (ISM) algorithm used by SDD software, the 11 challenges articulated earlier in this report are further articulated by a selection of 6 representative Actions (blue boxes) that propose research projects or engineering tasks that address these challenges. The 11 challenges show the leverage points for productive development, from Challenge 34 (deepest driver) and Challenge 7 (next deepest and closely related). The six action boxes (blue, to the left) represent approach “solutions” from the SDD2 Pilot that were associated with relevant challenges. The proposal was that these actions would be generated by stakeholders in the next Collaborative Foresight (SDD2) workshop and would have cross-functional construct validity.

The structuring of outcomes, technical challenges, and solution capabilities within the Autonomy Discovery project can be accommodated in this hybrid method which we might call a cross-impact outcome map. Substantive links between the SDD1 influence pattern and the Third Offset can be defined in a cross-impact outcome map. The (reduced size) image presents the flow logic of the SDD1 influence map (left) linked to strategic outcomes and impacts drawn from the Future Operating Concept (FOC) and Endsley in the right hand section (Zones 3-5). A continuous logical flow of relationships between the ISM and outcome maps can be described in a form that should present a credible type of trajectory schema. The ISM, define by SDD stakeholders, maps the relationships of challenges that, when addressed, influence other challenges. The ISM “results” or terminates in Challenge 47, which can be defined as the strategic goal of the map. This challenge/goal is overlaid in the map’s center, and initiates the linkages of enabling outcomes (orange) and impacts.

The right side of the map was developed as a proposed approach using the Outcome Mapping method, and the content in the bubbles was drawn from current guidance and Secretary of the Air Force (SecAF) source materials. This extended map connects the most-influenced challenges of the ISM (Challenges 2, 76, 47, 68) to their logical outcomes in the complex series of outcomes and impacts that lead to a single strategic impact.

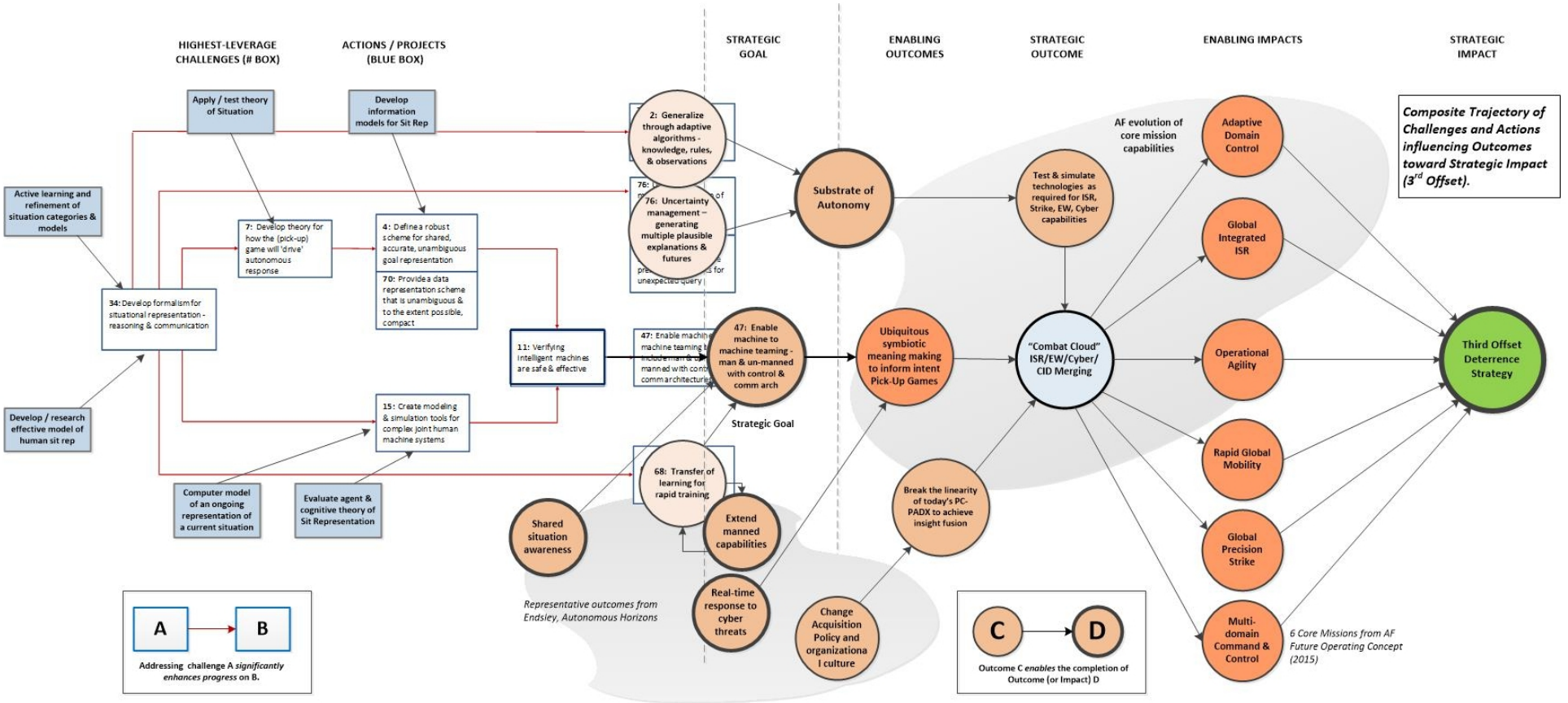

Figure 6. Proposed Technical Trajectory - Challenges and Actions, Outcomes and Impacts

The headings above the five sections of the Outcome Map identify the logical types for the outcome factors: Outcomes, Strategic Goal, Enabling Outcomes, Strategic Outcome, Enabling Impacts, and Strategic Impact. The factors for these six types were selected from both USAF strategic literature for autonomy, and several themes selected from the first Discovery workshop. To maintain coherence of the proposed mapping approach, only a small number of each type were selected for the model trajectory. The gray shadows underlying sets of outcomes and impacts show relevant groupings of factors associated with a source, but they could group programs, organizations, or mission functions in a work product.

The model trajectory retains the original visual syntax of the two mapping methods so their relative contributions are apparent and can be sorted out for this application. In a final product we might resolve the differences between the two methods and construct a visually integrated hybrid trajectory that accommodates the logical relationships inherent in both methods. The proposed next step for AFRL if adopting this trajectory as a planning resource would be to assign “swimlanes” and resources to the actions at the left end of the map.

5.2 Outcome Mapping Analysis

The Air Force Future Operating Concept (FOC) establishes the desired future of Operational Agility through the evolution of capabilities that leverage advanced technologies and doctrine toward the Third Offset strategy. The desired strategic impact of these capabilities is to provide Operational Agility through Integrated Multi-Domain Operations. Human-teamed autonomous systems would play a deep role in each of the mission capabilities.

As presented by Deputy Secretary of Defense Bob Work (*The Third U.S. Offset Strategy*, Jan 28, 2015) and Secretary of Defense Hagel, the Third Offset Strategy (strategies) consists of long range R&D and innovation including robotics and system autonomy, miniaturization, big data, and advanced manufacturing. More recently (November 2015) Work has described the innovation in autonomy as "Human-Centered Autonomy." The FOC develops the applications of Human-Centered Autonomy in airman/combat scenarios in 2035 for each of the five mission capabilities.

Of the five, Global Integrated ISR bears the closest relevance to integrated Autonomy capabilities defined by AFRL to date, and Multi-Domain C2, and Adaptive Domain Control to a lesser extent. Each of these missions are defined in the document as being supported by the appropriate balanced mix of assets, repeatedly cited in the document as:

> *“the term “unmanned” … has become inadequate to describe the variable roles that Airmen play across the spectrum of remotely operated, semi-autonomous, and autonomous assets that the Air Force increasingly operates in air, space and cyberspace.” (6, p. 11)*

The FOC incudes few direct references to autonomy, and it has even less emphasis on “fully autonomous” than perhaps suggested by previous Concept of Operations (CONOPS) references. The document precisely designates the roles of airmen and of “uninhabited” assets, which are to have limited authority:

> *“When mission needs dictate, some uninhabited systems can conduct increasingly autonomous operations under appropriate degrees of human supervision, such as human battle managers in control of large numbers of*

self-coordinating vehicles or programs. This flexible arrangement of human-system integration relies on advanced automation to reduce human task loads, enabling Airmen to focus on critical activities like situational understanding, mission-objective selection, and targeting."(6, p. 21)

This carefully explicated development of human-system integration suggests the strategic positioning of Robert Work's references to human-centered autonomy is already being incorporated in USAF strategic planning. These are the mission capabilities being positioned for the Third Offset strategy, and human intelligence is given a significant privilege in the roles of coordination, decision making, and execution. Such a scenario is developed in the segment "Human-Systems Integration at the Tip of the Spear" (6, p. 22) involving manned aircraft leading the sortie to cue and triangulate Mobile Mortar Locating Radar (MMLR) by "uninhabited aircraft."

5.3 Proposed Autonomy Collaboration Approach

We recommend at least two workshops addressing a hybrid of three proposed options (involving QuEST, human-machine teaming, and the deep driver of Situation Representation formalism). These workshops would be symposium-like workshops of three to four days involving a wider variety of participants and external stakeholders (researchers as customer model). We would recommend the SDD co-laboratory workshop follow closely to the original application plan, which is included in the Appendices. We see Workshop 2 (December 15, 2014 was Workshop 1) as flushing out the setting, plot and key elements of a narrative defining a scenario for a demonstration that would develop requirements for Situation Representation. Workshop 3 will use this scenario definition to establish recommended solution pathways that help solve key policy and R&D problems for a revolutionary QuEST-guided autonomy approach. Together these workshops would contribute to the elements in the Common Technical Trajectory: The Strategic Impacts, Outcomes, Challenges, Drivers, and Solutions to challenges within a system mapping constructed by leverage of each element on the others in common.

Considerations in the design of the collaborative foresight (SDD) workshops include:

- ***"Symposium" approach****: Rather than holding follow-on SDD workshops, a multi-day symposium structure might be convened that would enable a full day of open discussions (if new stakeholder views are being brought to the research collaboration). This will enable sufficient context to follow the discussion period with up to a two-day structured dialogic design workshop.*
- ***Expanding stakeholder dimension****: Significantly expanding stakeholder representation will encourage collaboration building across AFRL and the broader research and technology communities interested in human-machine autonomous systems. Identified external stakeholders from industry and academia will ensure AFRL addresses known gaps in developing autonomy systems models, and will discover "unknown-knowns" that other stakeholders and scientists have insight to, from outside the current scope of AFRL research expertise.*
- ***"Researcher as Customer"****: Rather than focusing on the future operational user (e.g., ACC) as the primary customer stakeholder, the research community in autonomy/human-system sciences might be engaged as the "user" of the outcomes from the next collaborative foresight workshop. This positon would*

encourage the adoption of creative approaches for immersing participants in a futuristic narrative for envisioning scenarios of provocative autonomy situations.

- ***Revolutionary R&D scenarios****: In order to envision a higher variety of plausible and significant solutions or outcomes, a revolutionary (disruptive to current organization trajectories) approach to scenario for autonomous sensing systems might be employed, per the DSB and AFRL strategy guidance.*

5.4 SDD Collaborative Foresight Workshop 2 Proposals

Three options for the content focus in the next workshops were proposed in the final report for the December 14, 2014 Collaborative Foresight Workshop. These were:

Option A: Deep Driver Deep Dive. This is the default approach to the SDD collaborator, to focus primarily on deep driver (C34) situation representation formalism for reasoning and communication.

Option B. Quest as Driver For AFRL Collaborative Initiative. This option is for a discovery-oriented workshop to enable collaborative foresight of QuEST as technology driver for the AFRL Autonomy Initiative.

Option C. Human-System Integration. Option C extends the prior workshop deep drivers (C34 and C7) to fully recognize and integrate human system challenges, identified as Challenges 18 and 30 (received votes but were excluded from structuring due to time constraint).

Across all sets of options, we recommend that significant attention is paid in our planning and engagement to introduce other Air Force, military, and external stakeholders working in autonomous systems, autonomous ISR and operational technology, and human-centered autonomy. The following proposals should be considered in any future workshops, from our experience in the planning and workshops to date:

- ***Futures Narrative****. Set up a specific, well-formed future scenario informed by the background research into the deep-driver problem area of situation representation in emerging "pick-up game" situations. The future narrative (near-future science fiction) work The Situation and the graphic illustration of the story would be provided to all participants as an engaging and vivid encapsulation of the significant concerns and technological possibilities inherent in these scenarios. The Situation narrative (provided with this report as a separate appendix) will provide a common reference to these complex emerging technologies in an action setting, the possible functions of human-machine teaming relying on distributed and contested situation representation, and the terms and lingo used and understood in the Air Force today.*
- *Support the scenario with input from stakeholders in academia, industry, OPS, T&E and Service Labs. Stakeholders would be invited to read and comment on the narrative in advance of the co-laboratory workshop.*
- ***Aligning current roles with future considerations****. Further the tangibility of futures thinking by assigning roles for participant interaction such as:*
    - *QuEST members would play their own role in driving an integration of human-machine symbiosis entailing engineering tenets derived*

from human consciousness studies. (That may be an agreeable definition of QuEST).

- *Other roles would be developed for Third Horizon EW, Cyber, Strike, ISR (and other future types of) operators. Futuristic roles would enhance diversity including Judge Advocate General representatives, civilians, privacy advocates, and ethicists.*

- *Roles for those who understand human habits and patterns such as cognitive scientists, systems sociologists, clinical psychologists, anthropologists, etc.*
- *Roles for those who understand change such as social systems, risk management, organizational theorists.*
- *Roles for those who understand information and communication from network theory, complexity and systems theorists, biological, anthropological, and social perspectives. Roles for interpretative disciplines and hermeneutics such as philosophy of science, of mind, theology and belief systems, and artificial intelligence.*
- *Employ explicit provocations from the future context being explored in the session, such as a futuristic avatar to frame the Trigger Question (TQ) for the workshop.*

5.5 Conclusions

This report concludes a major phase of work conducted for the AFRL/RYW Autonomy Discovery steering group under contract with TDKC. The report summarizes the work conducted and the outcomes of workshops delivered to AFRL organizations. Each workshop successfully delivered an engagement among key engineers and scientists as planned in the original proposal and plans. We recognize that the AFRL organizations are making impressive near-term progress on autonomous sensing systems for well-identified operational problems. There were several goals entailed in the collaborative workshop plans, for developing a common technical vision and trajectory that might unify projects over time toward meeting the far-term objectives of the Air Force, which were not met.

The two successive workshops planned to develop a unifying technical trajectory based on this work were not convened or completed. While these workshops were planned and ready – on two different dates after the December 2014 SDD workshop holds were requested by management for staff schedules and emails were composed to invite internal and external stakeholders. In both cases the scheduling broke down for key stakeholders and the workshops were delayed. Schedule conflicts also resulted in very poor attendance for the “SDD2 Pilot” December 2015, from which we attempted to collect meaningful data to continue with the project.

After working closely with the AFRL organization for roughly two years, we can advance several lessons learned that might be considered if renewing this work or attempting a serious collaboration in human-machine autonomy or other highly complex sociotechnical problem areas requiring trans-disciplinary collaboration.

We might identify a number of lessons learned for AFRL from this project and for consideration in future collaborative engagements or workshops of this type.

- *From the very outset, in the first Discovery workshop, there was an expressed concern outside the technical issues being explored for the challenge or barrier of "organizational stovepipes." Even though we could not integrate this organizational process issue into the technical challenges effectively, the challenge was well-understood in the background by all participants, and yet we had no effective plan or approach to release the hold of this challenge on proceedings.*
- *There must be a sustainment of organizational commitment over the period of time necessary to engage key external stakeholders and a broader range of AFRL staff and management together in deep collaborative workshops. The outcomes of the series of SDD collaborative foresight workshops would have significant organizational and planning impact if they were followed in a dedicated way. These engagements take time and commitment to establish and then to coordinate new commitments within the organizations and projects associated with the common technical trajectory.*
- *There must be top-level management support from the outset for collaborative ventures. There is an explicit in this setting for "top cover" commitment to management, spanning reporting lines of the organizations to be involved. There is a need for early involvement of management rather than requesting permissions and navigating gatekeeping at the time of execution of plans.*
- *AFRL management and staff forging collaborations across organizations were adhering to a well-understood dictum for staff to 'stay in swimlanes,' preventing new collaborations from being forged in our proposed process. The call for collaboration even by top leaders must be accompanied by adjustments to changes in evaluation of management. There is not yet an acceptable language for speaking of collaboration across organizations (and across swimlanes of defined collaborations). As individuals there is no incentive, there is in fact disincentive to identify or even acknowledge the need to work across disciplines.*
- *The call for working across boundaries, organizations, disciplines made at the top level is not translating to the researcher level.*
- *There must be a mandate for follow-up and meaningful debriefing. What is endorsed as focus by the group must be followed up by their own managers. Running the event and distributing the products is not enough. The points of collaboration called for should be put into a proposal, endorsed by the signature of all the participants and go to the lowest level of management which is above all the participating as well as organizations nominated for future involvement.*

- *There was an attempt, due to necessity, to employ Dr. Weigand in his broker role to fulfill the role of sponsor. The sponsor's role is as a convenor and organizer across divisions and directorates, and external stakeholders. Dr. Rogers was the "lead sponsor" who provided advice and leadership across the project, but he was not in the right position to be a convening sponsor. No one stepped up to this role or catalyst, but instead senior staff (and management) in effect served as gatekeepers whether intended or not.*
- *Consultants could not advise themselves up the chain to address these issues. Attempting to have the broker address these issues appeared to place him in an untenable position of being an agitator and seeking permission.*
- *There is a structural problem in conducting collaborative initiatives through externally supported workshops, since the level of contract issuance was below the necessary management level for endorsing a project which intended to identify boundary-spanning engagement. These arrangements needed to be made at the point of proposal and pre-contract, to establish the mandate for the work with clear management purview. This arrangement might challenge the status quo, as is called to be done by the executives and not technical staff.*

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APPENDICES

A. The Situation – A Narrative Future Scenario
B. SDD Application Plans
C. Stakeholder Analysis
D. Index of Stakeholder Organizations
E. Proposed Autonomy Taxonomy Model
F. Structured Dialogic Design – Challenges Analysis

Appendix A. The Situation – A Narrative Future Scenario (abstract)

DDI coordinated the development of a science fiction narrative specifically for the purposes of the SDD workshops, to provide a detailed, compelling illustrative scenario for all particpants to read in advance of the workshops. The purpose of the narrative was to enable all particpants to envision and understand the key issues at stake in the Collaborative Foresight workshops by vividly describing in a compelling story the possible technologies, intelligence and operational methods, and command situations relevant to situation representation in an emergent, ambiguous "pick-up game" problem where military action might be taken. A 20-year timeframe was established for the narrative as pertinent to the foreseen technology trajectory of functional human-machine autonomy in a future where the Air Force mission functions have integrated into a "combat cloud," and that advanced collaborative decision technologies might be employed to interrogate the best human intelligence through mixed-presence virtual engagements to bear and decide on a complex problem. *The Situation* explicitly discusses features of AI-based autonomous systems within a plausible geopolitical pick-up game scenario, providing a common conceptual baseline for critical dialogue.

We believe that not only external stakeholders but AFRL scientists will benefit from reading a common narrative with detailed operational situations that might offer a tangible and memorable set of references that would facilitate the efficient and productive structured dialogue in the SDD process.

Written by one of Canada's top science fiction authors and future science thinkers, Karl Schroeder, The Situation was written consistently with several other works he prepared for Canadian Forces and other US DoD projects over the last decade. Accompanying the narrative we provided a graphical map as shown in Figure A-1 (illustrated by Patricia Kambitsch) in a gameboard style that illustrates the plot and characters of the narrative, describes the main concepts and problems engaged in the story, and allows particpants to quickly glance and recover issues for clarification and discussion over the course of the workshop.

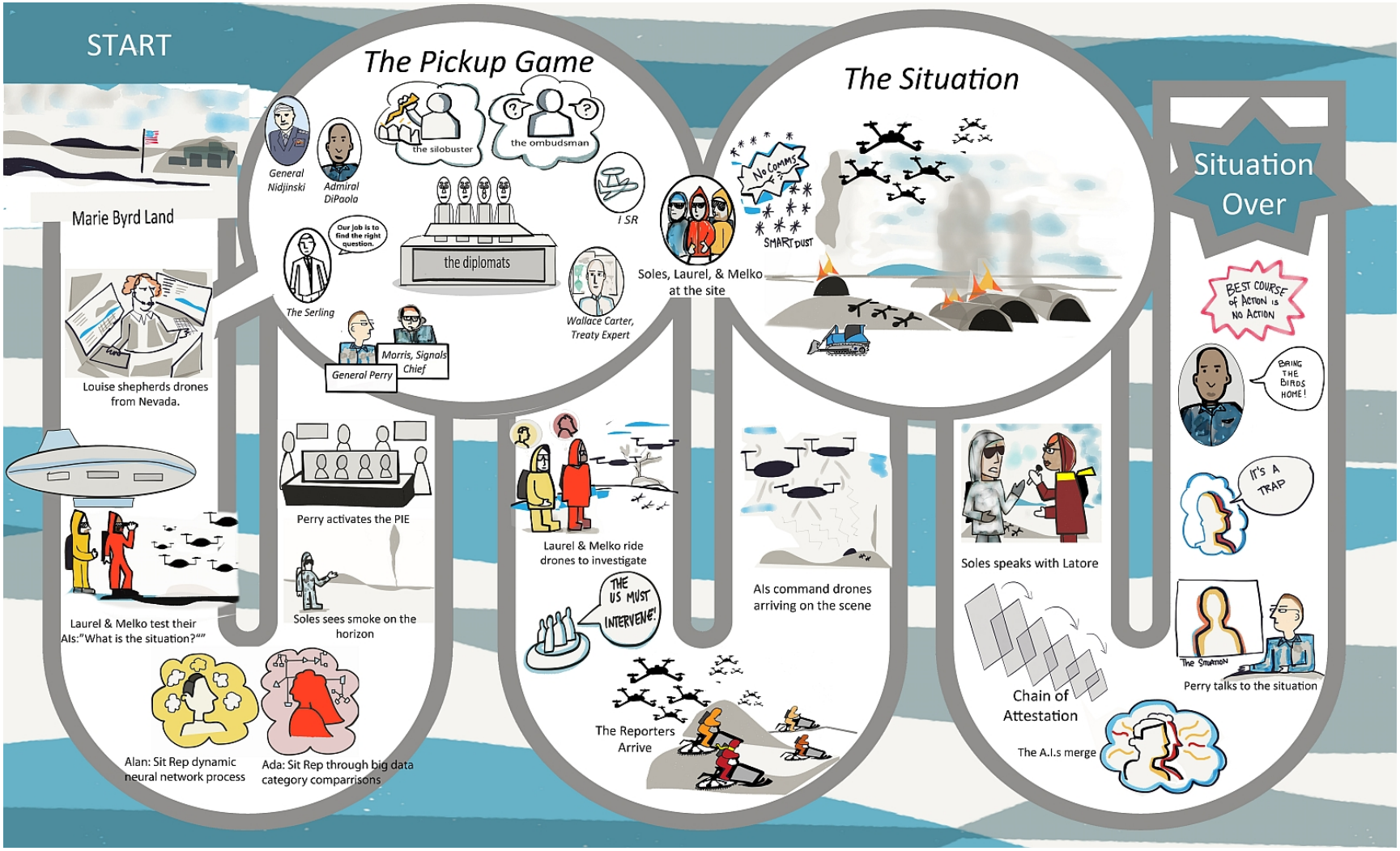
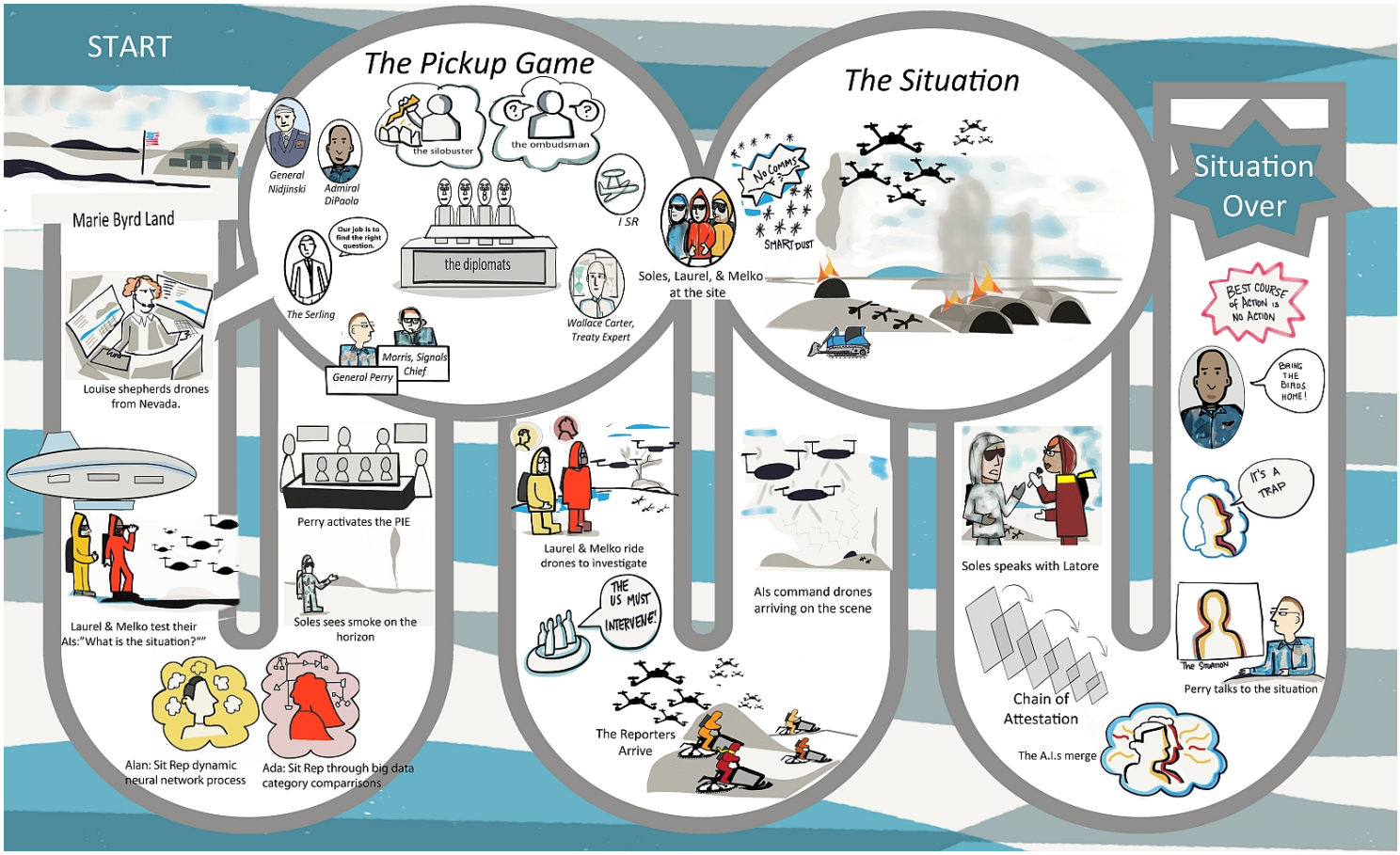


Figure A-1. The Situation – Visual Narrative.

THE SITUATION



Written by Karl Schroeder
Narrative Futures, Toronto

For Dialogic Design International
and The Knowledge Design Company, Dayton
Illustration by Patricia Kambitsch, Playthink

THE SITUATION

The big drop-door levered down into choppy air, revealing purple-shadowed Antarctic hills a thousand feet below. Louise Gapenne held her breath, swaying side-to-side with the motion of the thickly bundled figures standing in the hold of the giant hybrid airship. During her first week as a swarming drone operator she'd been quite self-conscious about how she moved; she was, after all not on the airship at all, but seated in an office chair in Nevada, halfway around the world from her birds. Still, the virtual reality visuals were good enough to give her motion sickness if she didn't window the video feeds.

One of the seven people in the hold raised a mittened hand in a clumsy thumbs-up. It was one of the researchers, not a member of the fire team escorting them, but the parkas were so bulky she couldn't tell if it was Laurel, the woman, or the man Melko. Both were crazy to be down there in person; the air temperature was -30 on the ground.

"Commence drop," said Melko's voice, crisp in her ear. The airship was idling forward at its minimum airspeed, a mere eighty kilometers per hour. It was tricky for it to maintain altitude like this: its airfoil-shaped gasbag didn't contain enough helium to keep it aloft without the lift of forward motion. This maneuver would have been a lot easier for Gapenne if it had been able to stop completely, like the old zeppelins.

"Drones away," she said. Through her headphones she heard Laurel--who wasn't wearing a mic--swear as her quadcopters lifted into the turbulence of the hybrid's cargo bay. One, two five, ten of the meter-and-a-half wide things toppled out of the hybrid in a disorderly flurry of black plastic and whirling vanes.

All 20 of the quadcopters were outside now, keeping pace with the airship. Ten belonged to the ship and were under her command. The rest... Three of those swept back into the airship's hold and hovered. Melko hefted a backpack shrouded in arctic camouflage, and heaved it at one. The device adroitly snatched it out of the air and disappeared into the sub-zero air outside.

"Melko, what was that?" she asked. She didn't like the idea of the things improvising that close to her ship.

"It's in the chain of attestation," he said. "Check it out." She rolled a window into her visual field and flipped back through a sequence of freeze-

frames, quickly verifying that the pack had been filled under supervision back at the base. "Our bots already found a good place for us to camp," Melko continued. "They're setting up." Two more of the autonomous drones flew in to fetch equipment--a tent bag, fuel for the heaters, a solar array folded like origami. "Sergeant?" Melko said to one of the white-suited members of the fire team. "Have we got your permission to start?"

She saw Sergeant Soles give a thumbs-up, and Melko turned to look at Gapenne's hold camera. "You can drop us off where those drones are working."

Louise flipped her view to the first of the research team's drones. It was falling at alarming speed toward the swirl of rock and ice that was all there seemed to be on Fletcher Peninsula. Apparently that rock hadn't been visible at all until a few years ago. The retreat of the glaciers continued to uncover ancient bedrock--and fabulous mineral wealth--here at the bottom of the world.

Ten years ago she'd never even heard of Marie Byrd Land, and could never have imagined she'd be shepherding drones there. That was before the South American Union descended on Antarctica to claim vast parts of it.

The United States had long ago staked its own claim on Marie Byrd Land but, like most other nations, had never tried to enforce it. With the current gold rush, it was prudent to keep a toe-hold on the continent; so one lonely USAF base clung to the edge of Marie Byrd's coast, busily doing nothing other than keeping the flag planted.

She switched to a view that fused GPS, radar, sat and camera views in various frequencies. It made the ice-scape below resemble a number-strewn video game level, but flying was a lot easier this way. The airship had its own ideas about how to land, and she could see the projected course as an overlay of green lines. As usual she could take her hands off the stick and it would perform flawlessly; policy now allowed her to do that even though there were human passengers aboard. But she liked to fly.

It didn't matter that her own preferred approach was identical to the one the airship had chosen.

The airship cruised in, rock-steady, and touched down without a jolt on a seemingly infinite plain of snow. Melko and Laurel shouldered the packs and Soles turned to salute the interior of the airship. "Thanks for the lift," he said. "Just don't forget where we are."

She laughed. "No chance of that, Army." The autonomous AI researchers marched with apparent confidence down the ramp and into the bitter cold of the long Antarctican day. Four fire team members and their squad leader followed. She blew out a sigh of relief, and plotted her ascent.

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As the backwash settled, Sergeant Soles aimed a laser pointer at several half-buried packs the drones had dropped. The pointer made waypoints visible in his men's HUD goggles; without a word three of them jogged across the hard-packed snow to retrieve the packs. Soles turned to the two researchers. "Are you going to tell me what we're doing out here?"

"Field trial," said Melko. He was waving at one of the aerial drones, which hovered uncertainly forty feet away.

"I got that part," said Soles. "They briefed us. Autonomous sensing systems, sure. But what are we doing here?"

The two Ph.D.'s turned as one to grin at him. Cameron Melko was young, sandy-haired, with a hipster beard. His smile was more of a rictus of discomfort; it was at least thirty below out here. Terry Laurel, who was older, was also taller; Soles' mother would have called her 'big boned' because she wasn't fat, but solid. She seemed unaffected by the cold. Probably an Antarctican veteran, Soles thought.

"These guys are only part of the system we're testing," said Melko, waving at the drones. He didn't seem to have noticed that Soles was now scowling at them both. "We have occasional satellite recon, an upper-atmosphere blimp you can't see from here, then the big drones, and a flock of hand-sized ones."

"Flockers." Soles nodded. He'd seen the things in action. They could coordinate by the hundreds; one bird-sized drone was cute, but a sky full of them was terrifying.

"Dr. Laurel and I have a little wager," said Melko, still grinning. "We've been working on different approaches to situation awareness," Melko went on. Behind them, under Soles' silent direction, his men were raising the first of two brightly colored dome tents. "Both of us are at the field test stage, so the Air Force decided to run a trial in parallel."

"Once we're set up, we're going to wake up our AIs and ask start a pickup game," said Laurel. "The first team to figure why we're all here wins the game."

Soles stared at one of the circling drones, then said, "And what's the correct answer?"

"The correct answer," said Laurel archly, "is that we're testing the idea of the pickup game itself. But the bots have to figure that out on their own."

Soles paused in trudging. He turned slowly to scan the horizon, which consisted of low hummocks of ice and snow, with a distant rock ridge hulking black some miles to the north. Nope; there was nobody else here to talk to. He decided to play along. "What's a pickup game?"

"It's exactly what happens when you and some friends walk into the park with a baseball and bat. Whoever's around joins and you make do with what you've got. Most situations in the field aren't perfect--we don't have access to all our resources," said Laurel. She looked down her nose at Melko. "The real problem is, how do the players agree on the game, or even that they're all players? Do they share a protocol beforehand? If so, how do they react to a situation that falls outside that protocol? Melko and I have been evolving our AIs to use very different thinking styles. We're going to see which one works best."

"There's a dark side, too," said Melko. "You know they used a lot of autonomous drones in the Central Asian War. They were badly programmed--classic killer robots. We have to prove that our systems can act autonomously and still follow the Geneva Convention scrupulously. Actually, they've got to do better than that. If there's a human in the loop, should an autonomous AI follow that humans orders even if it's told to commit an atrocity? That would mean we'd programmed systems to obey us even when they know better--in order words, to use the Nuremberg Defense, that they were 'only following orders.' Is that ethical on our part?

"Anyway, I'm going to win," he said to Laurel. "Your AI's totally reliant on a computational backend that's elsewhere. It has to phone in to be able to think at all. But what happens when we lose communications?"

"Which," said a member of the fire team as he approached, "we seem to be doing." He was shaking a sat-phone by his ear. Soles had already noticed the degradation of the satellite connection, but since the weather was supposed to be good for the next twenty-four hours, he wasn't concerned. He said so, adding, "Do you two want to continue even if we lose Signals?"

"Since I'll definitely win now, yes," said Melko.

"Melko's problem," Laurel confided, "is that he hasn't thought things through. In order to act autonomously with limited computing resources, his system faced two choices: To try to fit what it sees into pre-built, canned scenarios; or, to make up its own representations, which may not make any sense to the people it's reporting to. In that case it might be really intelligent, but if there's no point of common reference between what it's thinking and what we understand, then all its cleverness is useless. Some common high-level representational language is necessary or the 'players' can't even agree on what's a bat and what's a ball."

"Mathers," said Soles, grabbing the arm of one his men as he passed, "how long till sunset?"

Mathers tapped his goggles. "Two hundred hours, sir."

Soles sighed. It was going to be a long day.

"Sir," said another member of the fire team. The tents were up now, and the man was holding a catalytic heater, its vent hose drooping over his arm. But he was pointing with the other. "I thought we were supposed to be alone out here."

"We are, Pinker."

"Then what's that?" Soles looked where Pinker was pointing.

Silhouetted against the violet smear of the eastern horizon, a thin plume of black smoke was rising.

#

Major General Neal Perry liked to walk. It was effectively impossible to do this in the narrow corridors of the Marie Byrd Research base, which was little more than a set of interlinked trailers huddling under a geodesic dome. So, he had learned to ignore the bitter cold outside.

After many long turns around the dome, he had begun venturing further and now had a favorite destination. About a mile from the base, bedrock erupted from the ice field that sloped relentlessly north to the ocean. This cold black knuckle of ancient rock was the tip of some submerged coastal mountain, and he liked to hike out to it and stand on it for a while.

In doing so, he knew he was planting his feet on the only land on Earth not owned by any nation. When the call came in on this particular day he was out there on that rock, considering what it would feel like if tomorrow it were suddenly part of the United States of America. Which it might well be.

"Sir? Satellite reports thermal activity two hundred miles due east of us."

He put his hand to his ear; he wore heavy flight crew earphones when he walked because they doubled as muffs, and he always kept his radio on. "Relax, captain. We dropped off a research team there about an hour ago. They're probably setting off flares." In any other command, he wouldn't know every detail of every operation the way he did here; but little happened in Antarctica. It was easy to keep up.

"Unless those flares burn two hundred feet high, I don't think it's them sir. Anyway, this is a few miles east of their position."

"Do we have anyone there? All flights accounted for?"

"All birds are home or on their way, and there are no known bases or installations in that area."

Odd. "I'll be right there." He started back to the base, following his own trail of footprints, which after six months was turning into a well-defined rut.

There were few possibilities. Unless a plane had gone down, this was either a natural phenomenon or somebody doing something they shouldn't.

The southern polar continent had been a quiet place, completely ignored in geopolitics--until the newly minted Bolivarian Union, a coalition of South American nations modeled after the EU, had turned its attention there eight years ago. Several of its member nations had rival claims in Antarctica, but nobody had cared until the calving ice began exposing rich mineral deposits, and oil was discovered off the coast. Suddenly those claims were priceless and the Antarctic Treaty was in precarious shape. Rather than fight over it, the BU countries set up a protectorate. The other nations with interests in the continent had noticed, and now a literal gold rush was happening.

"Scramble a flight of recon drones over the area. Have the satellite images been sent to IMINT? ...And any word from Antártica?"

Antártica was all that was left of the Bolivarian Union. Infighting and a currency crisis had caused the Union's breakup after just a few years, but not before it had poured billions of dollars and thousands of workers into the Antarctican Peninsula. The peninsula sprawled northward to nearly touch the southern tip of Chile and a host of mines opened. There was an administrative center on the island of Marambio and a deep-sea

port at Esperanza. When the Bolivarian Union collapsed, its Antarctican adventure had rebranded itself as the first independent nation of the new continent.

With a population half that of Iceland, Antártica was hardly a military player. Still, it might just be the straw that broke the Antarctic Treaty for the other powers.

Perry was hurrying by the time he pushed through the double set of doors into the base. The place was lit by bare bulbs; it might be day outside, but the windows only let onto the parking and staging areas under the dome. It might as well be night, and there was nowhere on Earth where military time made more sense than here.

The base's senior staff was waiting. Perry smiled wryly; their attentiveness wasn't because this was an emergency, but because literally nothing else had happened down here in months. "I suppose you'll want to use the PIE," he said to Morris, the Signals chief. Morris grimaced; everybody knew he'd been itching to move operations from the dispersed hand-helds, augmented reality headsets and terminals the base currently used, to the Precision Information Environment.

"It's full of kitchen supplies," he grumbled. "And somebody put the ping pong table in there."

"Well, this will give you an excuse to clear it all out." While Morris directed the kitchen staff to clear boxes off the chairs and central table of the PIE, Perry sat down with the staffers.

The PIE did take up a lot of space, which was at a premium here. It was a simple rectangular chamber containing a number of workstations and visualization tools. Leading off of it were several conference rooms. The conference tables looked ordinary except for the glass panels that ran down their centers. These were the latest in telepresence technology, able to project the images of people from anywhere in the world, as virtual meeting participants.

The PIE took up the space it did because it conformed to the exact dimensions of hundreds of other PIEs around the world. You could combine PIEs in different sites into one virtual space whose inhabitants were partly local and physically real, and partly projections from the other sites.

One of the imagery analysts walked in, his face half-obscured by a bulky augmented reality rig. "Ah," he was saying. "Right."

"Corporal Eden, share please," said Morris. SIGINT turned his head, noticed the table full of senior officers, and said, "Yes, sir." He began making gestures like he was catching invisible butterflies, but when he then tossed these, the walls lit up with what he had been seeing. He took a seat at one of the side consoles, which had a multi-screen setup. On those--and the walls--a series of grainy satellite photos was flicking by, faster than Perry could follow them.

"What are we seeing, Eden?" asked Morris. Perry glimpsed jumbled aerial views of black stone canyons, a vast flat plain carpeted in blue-white snow; glaciers; jagged hostile coastline, all stuttering over one another in bewildering profusion. Then suddenly the chaos stopped on one image, a long shot of the Antarctican coast--white ice on the right side, black water on the left.

"What did I see?" muttered Eden. A red square appeared in the picture, framing a small shape right on the shoreline. "Oh!"

"What is it?" asked Morris. Eden had only just realized he'd spotted something. The unobtrusive headpiece he wore was called a Registration Cap; it monitored his visual center's reaction to the quickly-shifting images and could alert the computer that Eden had noticed something before the man himself was aware of it.

Eden and the computer consulted, then he turned and said, "It's a dock. And..." He peered at the screens again. "Vehicle tracks. They go up the valley."

Perry nodded. They must lead to the spot of the explosion. Eden was following it and confirmed that supposition. Meanwhile the image processors had been combining what they saw with old LIDAR and GPS information to build a model of the mountain valley from which the smoke was arising.

The scene assembled itself in the wall display, piece by piece: a rutted ice road, terminating in what had once been a trio of quonset huts, all of them now aflame. Cylindrical gas tanks and squared-off lots surrounded these. At this resolution Perry could see squares that might be crates or equipment--and a few tiny cross-shapes that might be bodies.

A second track led from the quonsets to a broad fan of gray tailings where black mountainous stone jutted through the ancient glacier. Smoke was pouring out of an opening there.

"A mine, sir," said Morris.

Perry nodded. "How soon can we get boots on the ground?"

He sat down to draft a quick message to USPACOM and SOUTHCOM while the staffers conferred. He linked the files and incoming data streams, advising that he considered this to be a Type 5 incident for now. This meant that it should be resolved within a few hours. It was possible that it might escalate to Type 2 if there were casualties. A Type 2--which included plane crashes and terrorist attacks--might require extra resources, communication up the chain and notification at the General Staff level. He hoped it wouldn't come to that.

He paused, unsure what to title the message. Finally he shrugged and typed NEW SITUATION. Then he sent it.

"Wind's picking up," someone was saying. "It's going to make landing impossible for at least twenty-four hours. Whoever is down there is on their own."

Perry called up a table that displayed available air and sea resources. None could get to the site in reasonable time. Then he thought of something; he added ground forces to the display.

"Well, gentlemen," he said drily, "it appears we *can* get there. Seven of us, anyway."

#

Soles, their mandatory escort on this little adventure, turned away to radio in. Cameron Melko looked from him to the distant column of smoke then back again. The smoke was rising from the other side of a jagged line of mountain-tops that poked through the glacial plain. He shrugged. "Shall we start?" he said to Laurel.

"The cold getting to you?" she teased; but she was halfway into their tent already, and he followed her without another glance at the smoke.

They sat on either side of a catalytic heater that was cranked on max. Melko settled his augmented reality rig on his nose, and said, "Let's boot up." He and Laurel began gesturing in the air, like a pair of hi-tech shamans huddled around the modern equivalent of a campfire.

After the SitRep package loaded, little reticles began appearing in Melko's visual field. Each picked out the location of one of their aerial drones. He and Laurel had been forced to share the drones and bots, so as her systems came on line the reticles began shifting color, blue as his system took one over, red when it switched to working for Laurel. Both AIs

understood that they were time-sharing the bots--but not why. That was part of what they would have to figure out.

Lastly, Melko put on a Registration Cap. "Won't that be cold?" asked Laurel. Silently, Melko added a Montreal Canadiens toque.

When Laurel indicated she was ready, Melko cleared his throat and said, "Alan, Ada, *what is the situation?"*

Laurel coughed and shot him withering look. "You named your system after Turing?" Melko found he was blushing. Then she said, "Ada, build me a contextual representation."

Laurel had brought a little battery-powered Bluetooth speaker with her and they had agreed to patch the systems' audio output to it. Now Melko's system, Alan, said, "With our available manpower and equipment, and granting our isolation, we could do any of the following--"

"The situation is that this is a training exercise," interrupted another, female voice.

"Why, thank you, Ada!" crowed Laurel.

Melko stared at the speaker. In the corner of his vision, the bot reticles, which had flashed red momentarily, now all turned blue. 'Ada' had given them back to him; apparently she didn't need them any longer.

"As I expected," he said with a shrug.

Laurel frowned at him. "You expected to lose?"

"Actually, Alan got it right--"

Footsteps crunched up to the tent. Soles unzipped it and stuck his head in. "We're breaking camp. Need all your gear out of here."

His head retreated, leaving a gap and a blast of frigid air. "Wait, what?" Laurel surged to her feet, swearing, and went after him.

After a few seconds Melko the speaker and grabbed stuffed it in his pocket. He clambered out onto the ice sheet, to find Soles and Laurel arguing while the fire team stood like statues, inscrutable in their fur and goggles.

"--Can't get around those peaks on foot, and we're certainly not going to climb over them!" Laurel was pointing at the black spires on the horizon. A faint dark smudge still stood over one of them. "It's what, at least twenty miles!"

Melko barely made out Soles' nod, caged as his face was the fur of his hood.

"We have transport!" he said half-shouted. The wind was picking up, catching up threads of snow, making a haze on the horizon. "I'll need the drones!"

"Fine, we're done here anyway," she said; and Laurel remained calm and aloof for the next ten minutes, while the tents were broken down again and everything packed up. Then she saw what Soles meant by transport.

They had ten large quadcopters. Each was rated to carry a 200 lb cargo pack. Three now had bots, bags and gear hanging off them. Soles' men had clipped harnesses to the other seven.

"I'm not going to dangle myself off one of those things!" Laurel shouted. "We're not base-jumping here. This is literally the middle of nowhere!"

"Relax, we're not ascending." Soles stepped under the swirl of down-washing air beneath one of the drones. He folded himself into the harness dangling off it with three practiced movements. Then he gave a little hop.

The drone rose gently, until the line supporting his harness was taut. The quad-copter had aimed its jets a bit askance, leaving Soles, surprisingly, in a relatively calm zone. Laurel and Melko were getting blasted by the backwash, and Melko was about to turn away when Soles took a step.

He looked just like Neil Armstrong walking on the moon. He took another step, lifting a full foot off the snow. Then he made an easy, ridiculously long bound, ending up fifteen feet away.

"We call it moon-walking," one of the soldiers said to Melko. "You control the drone like it's a flying Segway, just turn or go or stop. The lift reduces our weight by a factor of six. Saves energy for them, compared to carrying us, and energy for us compared to walking.

"Orders are to circle north of the peaks and investigate the smoke. You ready?" A drone was approaching Melko, harness twirling in the snowy tornado below it.

Alan's faint voice mumbled from Melko's pocket. *"We could call in further support. We could split up, but that would be dangerous. We could discuss further options..."*

#

"Sir, message relayed from SOUTHCOM. USPACOM is also on the line. Antártica has made a request through diplomatic channels."

Perry called up the message and its context, which appeared as a network diagram on his private terminal. Spidery lines radiating from the message icon showed who had contacted whom, when, and under what authority. Apparently, Antártica had asked the United States government for help with an incident unfolding at their deep-water port, Esperanza. He scanned the message quickly, then began tapping its attachments and scattering them to the wall screens around the PIE.

"Attention," he said. "This is no longer an investigation of a single incident. Antártica says they've lost contact with Esperanza. It's been taken over, they don't know who did it. This happened at the same time as the explosion we're tracking."

On the wall, satellite feeds showed Esperanza, a frigid maze of shipping container-stacks, cranes, and white-roofed warehouses. "This is what we know," said Morris. "Esperanza is a container port, almost entirely automated, and it's huge. The Bolivarians used it to feed men and resources into the mines along the coast. The ice packs make it hard to get in and out for much of the year, so it has gigantic storage facilities. After the Bolivarian Union broke up it turned into a gray port, accepting cargoes from legal and illegal operations.

"Antártica is spinning this as a humanitarian crisis. We're in a position to do something about it. It's not going to look good if the United States stands by while terrorists overrun a major shipping port, even if we don't recognize the government of Antártica."

"I can't see any people," said Eden in the distracted tone Perry had learned meant he was interfacing with his headset. "The cranes are immobile. Unsure what's... hang on, it says I saw something." There was a long pause as Eden went back through his feeds. "There!"

One satellite image sprouted colored boxes and labels. "Most of the ships have stood-off into the harbor," said Eden. "That one's parked--is that the right word?--and empty of containers, but the cranes aren't anywhere near it. But there's a lot of light and activity around it..."

Perry asked for image enhancement, and some dark blotches near the ship resolved into human shapes. "They're armed," said Eden. "Could be Kalashnikovs."

There were glances cast between the people in the room. Perry could practically see the shared thought-balloon floating above his people: *somebody's taken Esperanza.* Pirates? Terrorists? Disgruntled dock-workers? The first conclusion led to branching possibilities and each branch

had its own set of usual suspects. He could call for detailed scenarios to be drawn up for each of these, present the deck to USPACOM and SOUTHCOM. He could call for an escalation of the incident level; it was looking like it could go to Level 2 now...

"Everybody hold it," he said. "As of this moment we're doing a reset. Consider anything you've inferred about the situation so far to be suspect.

"I'm starting a pick-up game. Morris, call up your assets."

#

Later, Louise would imagine what she had no time to experience at the time: the airship's glide in through the freezing, choppy air, the purple glow of the sky and faint amber light from the north touching the dark shape of a man reaching up to catch a backpack as it literally dropped from the sky into his hands.

Relieved of its passengers and cargo, her airship had quickly popped back up to five thousand feet. She'd waited for her ten quads to catch up, then turned due west to make for the main base at the Walker Mountains, 200 miles away. She brought in her drones and let the airship go autonomous again.

After a long, lingering look at the gorgeous vista of ice and ocean, she hauled off her headset and blinked around at the Nevada office. She stood up and pumped her fist in the air, and whooped--very quietly, so as not to disturb the other operators.

Scattered laughter from the support staff, and her supervisor Brinks grinned at her.

"Voler, you're up," Brinks said to Gapenne's partner, who was leaning over to high-five her. Gapenne was elated at how well things had gone, and eager for more. She shook out her tense muscles and reached for her coffee, and only then noticed the intense conversation that was taking place beyond the glass wall of her office. It was the supervisory team, in an apparent heated argument with a senior officer. Gapenne sipped her cold coffee and frowned over the orange partitions that subdivided the room like fences in a neighbourhood. Then she saw Brinks curse under his breath and nod. He stepped into the room.

"What's wrong?" For a horrible second, Gapenne thought she had screwed up somewhere, and her mind flashed back to the sequence of events: doors open, quadcopters down, then up--

"Better stake out a cot in the back," said Brinks.

She couldn't figure out what that meant, and just shook her head.

"They want us all here until further notice," he said. "There's a situation."

Brinks leaned over to type at a terminal, and the main room's lights dimmed. Then, the far wall lit up. Gapenne had noticed that it was white-painted, with ceiling-mounted projectors aimed at it. These now painted an image onto the end wall, of a crowded rectangular room of similar dimensions to this one. Brinks walked over to stand in front of the image. "Sir?"

One tall figure emerged from the clutter to stand opposite Brinks. "I'm Major General Neal Perry of the Antarctican expeditionary force. Colonel Brinks, I need to borrow your team's pilots. We have some unexpected reconnaissance requirements. I understand it was one of your people who dropped off a fire team on the Marie Byrd coast just now?"

What did I do? she wondered, as Brinks nodded and turned, spotting her. "Gapenne."

"Sir, Voler's flying the bird now."

"That's okay," said Perry. "I just want you to join an Intelligence pickup game. Are you up for it?"

She hesitated. "I don't know this protocol, sir. I've... never heard of an intelligence pickup game."

"That's okay, I'll spawn you a Serling to walk you through it."

He wasn't asking. Gapenne gulped. "Sir, yes sir, I'll do my best."

#

Perry extended another wall to include the PIE back in Langley, then turned to Morris. "Does the squad we sent to the mine site have the interfaces for a pick-up game?"

"I doubt it, sir..." Morris spoke to their liaison, then said, "Oh. They do. Part of their systems design."

"Include them in, then. Now," he said to the room, and by extension to the other connected PIEs. "I want a reset. Morris, build me an ombudsman. We need a new question."

Perry ran through a mental checklist of the different commands, departments, and bureaucracies that might need to be negotiated for him to reach out to all the assets they might need.

"Morris," he said, "we've got the budget for a silo-buster. Let's use it."

Morris grinned. First, he'd been given a chance to run the PIE; now, he had permission to activate the bureaucratic-barrier hopping mechanism the Forces had recently introduced to speed lateral and vertical communications. He turned back to his console, flexing his fingers.

"One silo-buster coming up, sir!"

Gapenne donned a pair of VR glasses and found herself in a basic white-room construct. There was a tall thin man in a suit here--or, she knew instinctively, not a man but a training persona. A *Serling*. It introduced itself and started to give her a whirlwind tour of the pickup-game process.

First came the *reset,* a deliberate examination and abandonment of the team's assumptions about what was going on. Then, an *ombudsman* was invoked. This was a role, often a machine-guided persona similar to the Serling, responsible for questioning assumptions. It essentially set the rules of the game. Without the reset, the participants in the game would more often than not follow a confirmation-bias heuristic, trying to fit whatever information came in to the very first model of the situation that had come to mind. "Do you understand these ideas?" the Serling asked Gapenne. When she nodded yes, exploded the white-room illusion, placing her back in the PIE. "Here's what we know so far," it said, and it told her about the mine explosions and the supposed assault on Esperanza.

"The key to a pickup game," it told her, "is understanding that these facts are all answers, in a way; our job is to find the right question."

The virtual room was quiet for a while; Gapenne talked quietly with the Serling as the rest of the team invoked assets who would become players in the game. Some of these assets were human, such as Eden, and there were command personnel such as Perry and USPACOM'S Commander Di Paolo (who wasn't likely to be hauled into the discussion at such an early stage). Some were stakeholders, reps from Antártica, Norway and other potential players in the political scene. Most of the reps were software personalities--*liaisons*--that, like actors, personified various groups or individual who wouldn't or couldn't actually be brought into the conversation. Their responses, the Serling told Gapenne, were based on the latest intel and organizational profiles. In short order Perry's team had populated the conference tables with virtual Bolivarian Union loyalists, separatists, Australian expansionists and Norwegian expansionists. Sensing

services would play too, and Soles' squad at the mine site. Gapenne was amazed at how quickly it all came together.

"Once upon a time," the Serling told her, "queries from the Commander would have fallen into different organizational silos, results would have popped back up, and the team at the top--Commander Perry and USPACOM, for instance--would have assessed their options. The problem is that information flow is painfully slow with this up-and-down approach, and nearly impossible between the silos. It inevitably gets filtered and distorted as it moves. So in addition to the ombudsman, we're using something called a *silo-buster*.

"Behind the scenes, the ombudsman is assigning each player an anonymous identity and a special role: analyst, auditor or critic. Once everybody's got their roles," he told Gapenne, "we'll play several quick rounds in teams. There will be no more than five analysts participating in each team. Each team tackles part of the question, with an auditor and critic from another team sitting in. You either participate, audit or critique, and then the roles are shuffled and we play another round."

Apparently it would only take two or three rounds until everyone involved in the process had crossed both hierarchical and departmental boundaries several times, and every relevant piece of information had been shared with everyone involved.[1] "If some understanding of the situation emerges during this process, that's good," said the Serling, "but its real aim is to uncover the next right action to take. The pick-up game aims at building directives, not representations. The silo-buster temporarily dissolves organizational boundaries to make this possible."

"You mean in this game I'm at the same level as him?" She pointed her chin at Commander Perry. The Serling nodded.

The figures--real and virtual--around the conference tables shuffled and intense conversations began. Perry was nodding in satisfaction, but Morris was approaching him, and he didn't look happy. "Sir?"

"Is there a problem?"

---

[1] This "game" is based on Syntegration, a group-oriented problem-solving technique developed by Stafford Beer and trademarked by Malik. Syntegrity is one of a few non-hierarchical meeting formats recently explored in management theory, in the class of systemic methods of dialogues as Structured Dialogic Design. (syntegritygroup.com)

Morris grimaced. "It's the fire team on the ground. Soles' squad. They're almost at the site of the explosion, I don't think they've encountered anything, but..." He looked uncomfortable.

"We've lost contact with them."

#

It didn't call itself Alan; in fact it didn't have a name for itself at all, merely a set of addresses. Even these were constantly shifting, as this or that drone's computing resources and sensors became available, or shut out the AI.

The two human researchers who did call it by the name Alan were arguing as they bounded in long preposterous steps across the Antarctic plain. The AI monitored that channel, as it did the soldiers' and for the same reason: to pick up clues about what to do next.

"So why did Ada win?" Dr. Laurel was saying as she cleared a set of ice dams with a single step. The AI's creator, Dr. Melko, had fallen significantly behind.

He said, "Your system assigned roles to the bots here, mostly sensors, asked them to assess what they were seeing, then did a big data analysis on a database of similar scenarios. Right?"

"Yeah." Laurel's cardiovascular indicators were up, but much less than Melko's. The soldiers were coping well. For now, the AI deprecated the scenarios in which the group had to stop to regain its breath.

Insofar as the AI had a body, it was instantiated in a shifting subset of the drones swarming around the humans. On waking it had been asked to explain the situation to Melko and Laurel; it was still working on that problem. At first it had seemed clear that their task was to run through some standard investigative routines and then return to base. Then, unexpectedly, a new objective had been provided--one that was slowly emerging into visibility around the long ridge of black peaks they were circumnavigating. Smoke was still visible above that.

"--System builds an internal representation of the scene," Laurel was saying, "then compares it with past events. Classic heuristic approach. And it worked!"

Melko made a skeptical sound. "Is it still running?"

"...Yeah."

"What's it saying now?"

There was silence from Laurel. The AI knew the names of all the team members, including its own designation as 'Alan.' Laurel and Melko kept referring to another team member, though: Ada. And this AI--'Alan' to them--could not find Ada anywhere.

Complicating its search was the constant time-slicing it had to perform with the drones. At any given time it could only control about a third of them. Another third was under Soles' command. The remainder was under the control of another nonhuman actor, apparently known as Ada. In theory Alan could communicate with this being; in practice, their messages back and forth had not so far made very much sense. Meanwhile, fighting Ada for access to the drones was an increasingly resource-intensive tug-of-war.

Another demand was put on its systems as Dr. Melko said, "Alan, what was the situation an hour ago?"

Translating that request into its own terms was difficult for this AI. It didn't think in terms of static descriptions, or representations, but in action potentials. After a second or so of translating the flow of events into human language, it said, "A group of researchers and a survival squad assigned to them were deployed to Antarctica to test autonomous situation-awareness systems."

Melko stumbled; luckily his drone corrected, lofting him into the air and over an ice spire that would otherwise have impaled him. "Did Ada tell you that?"

"Ada and I are not talking," said Alan blandly.

Laurel laughed. "I told you this would happen. Without some kind of common representational language, our kids aren't going to get along. Their frames of reference will be like quantum mechanics and relativity: they talk about the same thing but expressions written in one can never translated into the other."

"We'll see," said Melko. "My boy seems to be a fast learner."

The AI had heard Laurel's remarks and now it reviewed its recent exchanges with Ada in that light. Ada kept transmitting large blocks of data that assigned roles, positions and types to all the people and objects around them. It insisted that these 'representations' form the basis of their mutual understanding of the situation. But the AI didn't use representations; it swam in a sea of potential *directives* instead.[2]It wanted

[2] "Directive Minds," Andreas K. Engel, in Enaction, MIT Press, 2010, pages 228-230. Directives are an alternative to representation within the embodied cognition paradigm of cognitive science.

to frame everything in terms of potential actions, and Ada didn't seem to understand what that meant.

The moves in their game of resource management worked more like rounds in a *Prisoner's Dilemma* session. The AI was good at analogies, and it liked this one. As each resource conflict came up, it had two choices: retreat or block--cooperate or defect, in Prisoner's Dilemma terms. What if it started testing different responses? Always cooperate, always defect, or other variants?

All of this reasoning had taken place while Dr. Melko was drawing his next breath. Now the researcher said, "So, Alan, what's the situation now?"

"The team that was performing the test-run seems to be continuing it in a new pattern," said the AI. "The situation is that we're trying to find out what the situation is."

Melko laughed wildly.

"Cut the chatter," said Soles over the public channel. "We're coming into line-of-sight." With that he shut off their radios entirely, leaving the AI with only laser connections to its shifting components.

Emerging around the dark stone peaks was a long, trough-shaped valley. In the stark sunlight the AI's drones could see a line of blue ocean at the horizon, but the floor of the valley was obscured by a haze of wind-blown snow. Poking up through that haze were a number of dark, artificial shapes--a camp of some kind.

Soles pointed, a gesture that overrode the AI's control over the drone flock. The fan-driven machines settled in the lee of a tall thumb of rock at the end of the ridge. The humans unhooked themselves from their drones and the pack-carriers dropped their loads. For a moment nobody moved, then Soles swept his arms to bring the humans within voice range. "We have a problem," he said as Melko and Laurel joined the huddle.

"Yeah, I'm losing my uplink," said Laurel. Soles nodded.

"It might be natural interference--Southern Lights or something. But I haven't seen anything like it since I've been down here. Even the shortwave's being affected, which is weird."

"You think it could have something to do with...?" Melko nodded in the direction of the camp.

"Could be. We can't determine that from here. I'm going to send in the flockers."

With another gesture he sent sixteen of the hand-sized drones sailing down the valley. The AI had no control over them, but was able to piggyback on their transmissions; it watched through their eyes as they flew. Meanwhile Ada was keeping a set of commands in queue to send its drones to do a flyover of the distant wreckage. That action was currently blocked by Soles' order to stay down. If she were observing 'Alan' the way that it was observing her, she would see that it was currently passive, with no model at all of what was happening.[3]

Imagining how Ada would react to its actions gave the AI a new idea. By pretending it was Ada, it could in a way look back at itself, as if seeing itself from the outside. That might be useful.

"There were two heavy weapon impacts," Soles said confirmed as the flockers fanned out across the site. "One hit the main building and the other penetrated the entrance to the mine, causing a collapse. There are casualties, at least six, no survivors based on body temperatures."

Melko and Laurel exchanged a glance. "Maybe we should stop the test," said Laurel. "It doesn't seem right to keep it running when people have been killed."

"Yeah..." Melko frowned at the distant drones. "But maybe we can gather data these guys won't find. Alan knows how to do a forensic sweep, but they don't all have to be part of it. I say we keep the rest of them running our systems and see what they find." After a moment, Dr. Laurel nodded.

"On your nine, Mathers," said Soles suddenly. He had raised his HUD visor and was peering down the length of the valley using an old-school pair of binoculars. "Incoming from the North."

The AI focused its own attention there as some of the drones lofted into the sky for an aerial vantage point. Far away, close to the ocean, several little black specks had detached from the general haze and were wavering closer at ground level.

Soles flipped down his visor again. The cameras on the high-altitude drones showed a line of four skidoos, each carrying two people, coming up

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[3] Alan is engaged in a process known as registration. According to Brian Cantwell Smith, registration is the necessary pre-computational step in any process that results in the recognition of something. (Smith, B C., On the Origin of Objects, 1998)

from the sea. A small trawler was docked there; it must have arrived while the team was hopping their way around the ridge. The skidoos were following well-laid tracks that could only have one destination: the devastated camp.

"What's going on?" asked Laurel. Melko laughed.

"Aren't we supposed to answer that?"

Down in the ruined camp, Soles' men were taking up cautious defensive positions. The drones were still tightly under their control.

Soles sent three of the big quadcopters slaloming down the glacial slope, kicking up fountains of fine snow. The drones spotted something immediately--a drone swarm accompanying the skidoos.

"Attack platforms?" asked Soles. "Defensive?" But the drone's pattern-recognition software had another answer.

Camera drones. Whoever was approaching, they were brandishing the latest in full-immersion virtual reality multimedia recorders.

The AI thought about all the things those people might do with the drones, and all the reasons they might be here. It came to a conclusion at just as Dr. Melko said, "Reporters. That's just perfect."

The human team turned their full attention to that, which was a normal human reaction. Their focus was on themselves and each other. Something entirely different was nagging at the AI, however. Something about the scene of the explosion, and the bodies...

It turned its attention that way.

#

The situation's status had escalated, and was now Level 2. Perry sat at the PIE's central table, along with Pacific Command--USPACOM--and the Southern Command Air Force leadership who had been brought in at the escalation. Everyone at the table except for Perry was a virtual presence. In addition to the humans were several liaisons, the key one representing the fledgling nation of Antártica. In the past half hour Perry's email-with-attachments had been massaged, added to, and mutated into a brief, then a portfolio of scenarios complete with helpful visualizations. These were reeling by on the wall screen now.

"These Illegal mines are popping up everywhere," said Admiral Di Paolo, Commander of the Fourth Fleet. "Jurisdictionally, this is a SOUTHCOM issue. I'd be a lot happier if your people took care of it," he added in an aside to General Calvin Nidjinski, commander of SOUTHCOM.

Technically, Antártica was within SOUTHCOM's jurisdiction. "This may not be an Antártican mine, sir," Perry pointed out. "It might not be a mine at all."

"Forget the mine, our main concern is Esperanza."

"But sir, Esperanza's not within our jurisdiction."

"Technically, neither is the mine."

"But who blew them up?"

"I think you'll find they blew themselves up, Perry. Happens all the time. We're looking at an industrial accident here, not an attack. Esperanza, though--you've already identified hostiles at the port. It's piracy or terrorism and they've asked us to intervene. You've done fly-overs and we've modeled the entire site from the LIDAR scan. Since you and I started talking, the SEALs have run over a million simulated interventions and have a suite of tactical options ready. Politically, Washington thinks it will look good if we come to Antarctica's aid. It's low-risk."

"Sir." The situation was clear from Nidjinski's point of view, but doubt nagged at Perry. Part of that was radiating from the display showing the state of his pickup game: red lines joined many of the discussion groups, indicating that they were not in agreement about what was going on. "I'd like a few more minutes, sir."

Nidjinski scowled at him. "I'll give you five." He vanished from the table's holographics. After a moment, so did the rest of the senior leadership.

Perry blew out a breath and toggled back to the silo-buster. He said, "Antártica, would any of your people be likely to be mining in Marie Byrd?"

The liaison for Antártica appeared as a holographic person at the table. The would-be country's actual ambassador was on the line, but temporarily muted; this liaison wasn't human, nor did it formally represent Antártica. In some ways, a liaison was more useful anyway. It had a synthetic personality based not on how the entity it represented wanted to be seen, but aggregated from independently verifiable factors such as that entity's record of following through on promises, cheating, hiding information or, conversely, being open. This aggregate was partly displayed

as a Chernoff face,[4] the data about the organization's trustworthiness, for instance, being reflected in a tendency for the liaison to look away when talking, or fidget.

Antártica's liaison didn't look like the sort of person you'd take home to Mother.

Now it glanced away and shifted in its virtual chair. "We've put illegal mines into Queen Maud Land," it said, "so, yes, we might." Since the liaison was running on Perry's own servers--and not acting as a sock-puppet for Antártica--it could be brutally honest about the likely intentions of the people it represented.

Perry frowned. "Even though Marie Byrd is unclaimed, officially, we know the United States has an interest there?"

"Until recently, our biggest military opponent in the region was Norway. Even now, you only have one base on Marie Byrd."

Perry glanced up at the wall monitors. Antártica had broken the news about the attack on Esperanza and had told the world about its request for the United Sates to intervene. That was a diplomatic slap in the face, but they were playing the wounded bird, flapping its broken wing for all to see. Already, though, threads of the pickup game were telling Perry that three *Anzac* class frigates had departed Australian waters, headed south. New Zealand was dispatching transport aircraft, which likely contained troops. And the Norwegians, who already had a small base in Queen Maud, were scrambling some flights through the Canaries.

"What do we think's going on with the mine?" he asked the game's ombudsman. He noticed that somebody had given it a label: <u>the Situation.</u>

"We're still out of contact with our team on the ground," it said, "although Satellite shows they've arrived at the site. Player Nine thinks that Antártica built it, not because it will produce but as a grab for territory. They are doing the same in Queen Maud. Put a mine in unpatrolled territory and you've got squatter's rights. Antártica want the whole land mass. They're not going to stop at this."

"So who would have motivation to blow up one of their mines?"

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[4] Chernoff faces exploit the fact that the human brain is optimized to recognize very subtle differences in facial expression. This optimization means that ordinary people can spot very subtle differences in massive data sets if those data sets are mapped onto facial features.

"Anybody with an interest in the continent."

So, Australia, New Zealand, France, Norway... and us.

New information was scrolling on one of the wall screens. "Satellite now says there were two discrete explosions, about a kilometer apart," said Morris. "That doesn't sound like an accident."

Di Paolo was waiting on his decision on Esperanza, but the more Perry thought about these explosions, the more uneasy he became. The two were connected, he was sure of it. But how?

Morris sat up in sudden alarm. "Sir. I think you'd better see this." He brought up a newsfeed, with the characteristic breaking-news crawl along the bottom. The main image showed a brilliant white plain, wind lifting a layer of dove-gray haze off it. In the background, the purity of the white was marred by the black remains of a fire. In the foreground, a snow-suited figure holding a microphone was gesturing and talking.

Perry muted the game. "Bring that up," he said, and rolling Spanish flowed through the PIE. The simultaneous translation scrolled along the wall, and Perry's heart sank.

"...Could not make a clearer statement about American intentions on the Antarctican continent. From where we're standing you can see United States military personnel at the site of the attack. We had no idea when we were invited here that the brave, desperate miners who contacted us would meet such a fate. It's terrible, just terrible..."

Perry glanced at the clock. Di Paolo expected his decision in five minutes.

Five minutes...

#

On the other side of the planet, in Anchorage, Wallace Carter was nodding off when his phone vibrated in his pocket. He blinked, sat up, and looked around. A subcommittee chair of the Third United Nations Space Sovereignty Conference was still droning away at the head table. All eyes were on the tall, sandy-haired Finn, so Wallace took his chance and ducked out into the hall.

The conference center's windows looked out on blackness, as they had ever since he'd gotten here. The sun wouldn't rise for another week or so, but the lights of the town glittered cheerily above drifting scarves of vapor.

He put the phone to his ear. "Carter."

"My name," said a pleasant female voice, "is,--" click. Carter blinked; the brief digital noise was followed by the voice saying, "I'm the ombudsman for a United States Air Force Situational Awareness pickup game. I'm calling you today because you're listed as one our trusted resources."

Carter fumbled the phone, caught it in midair, and looked at the screen. The quantum-encryption told him that this call really was coming from the USAF. He'd taken robocalls before, but nothing like this. Gingerly, he put the phone back against his ear. "Yeah." Carter did intelligence analysis for a variety of high-level agencies; his expertise was space law. For this reason it made sense for the US Air Force to call him, but he wasn't aware of any current disputes in the lunar or asteroid prospecting efforts of the U.S. and China.

"Uh, how can I help you, um, what did you say your name was?"

"My name is," *click*. "Oh, I'm sorry, I see that no one has assigned me a name. To answer your question, I'd like to invite you to help our team explore a situation that is developing in Antarctica. Your expertise might prove useful."

He glanced back at the UNSSC meeting room. He'd rather pull his own teeth than go back there. "Sure. Where, with whom and for how long?"

"The meeting is virtual and floating; we can pull you in by phone. Speaker-phone would be best. Are you able to do that?"

"Sure." He eyed the center's atrium and the lunch tables there. They had been thoroughly picked over but he could see at least one untouched corned-beef sandwich, and the Coke was calling his name. There was a row of small meeting rooms on the other side of the atrium; he could camp there and chow down while he talked with Laurel's AI, and whatever friends it had brought.

"Catch me up," he said as he strolled through arguing delegates to the buffet table. "What are we talking about today?"

"I understand you're an expert on the sovereignty of unclaimed territories," said the voice in his ear. The only way he could tell Ada was an AI was that her voice was exactly the same as that of the real-estate robocaller that kept phoning to ask him if he wanted to sell his house.

"Sure," he said. "And you--look, it's kinda strange that you don't have a name. Can I call you..." He thought about it.

"I'm not a person," said the pleasant voice. "I represent the situation."

"Then that's what I'll call you," he said. "You're the Situation."

"All right."

"And you're a... what did you call it? Ombudsman? What does that mean?"

"I'm coordinating an intelligence pickup game," the voice said. "Your file says you have studied cognitive science. Have you heard of distributed cognition?"

"Yeah. Edwin Hutchins wrote a book about it called *Cognition in the Wild.* Idea is that in certain situations, thinking becomes a distributed activity, spread out over a bunch of people and instruments and stuff. No central thinker but a decentralized one."

"Exactly," said the Situation. "I coordinate a distributed cognition activity that involves numerous humans, artificial intelligences, instruments and agencies. I am not the one doing the thinking any more than any of them are. Collectively we are engaged in a cognitive activity."

"...Okay, then, Situation. What cognitive activity can I help you with?"

"Good," said the AI. "What do you know about Antarctican sovereignty?"

#

Ada watched the journalist gesture broadly and shout in evident emotion at the center of a cloud of drone-carried cameras. Sergeant Soles was watching intently, his physiological signs indicating some distress. He had directed some of the flockers to investigate the skidoos, and Ada had skimmed their data as they sniffed things and examined the newcomers at terahertz frequencies. They were unarmed. The biggest puzzle right now was why their comparatively crude satellite uplink was working, while the multiply-redundant frequency-hopping, encrypted military communications suite was not.

Ada (who knew its name) was aware that Alan was also focused on this problem. The investigation would go swifter if they cooperated, but so far they had failed to find a common language.

The reporter had identified herself as Maria Teresa Latore. She had just told the world that her team had been invited out here by an Antártican mining company to film a day-in-the-life story at one of their

camps. Now she finished her rapid-fire tirade and slumped slightly as the camera-drone drifted off to get wide shots. Soles approached her. "Ms. Latore," Soles said in his passable Spanish, "this is an active investigation. I'd like your cooperation."

"I'll film what I want!" She reared up, glaring at him. "This is international territory, I can come and go as I please!"

Soles was evidently angry, but instead of reacting, he stepped back to consult his tactical assistant. This little AI relied heavily on online resources available through its uplink, but that wasn't working. Soles shook it in frustration and turned away.

Ada had the resources the tactical assistant didn't, so it sent its owner, Dr. Laurel, an email.

"Look, it's true this is international territory," Soles said as he followed Latore. "But there may be unexploded ordnance in the area. It's not safe, Ma'am."

"I'll decide what's safe," said the journalist. His physical stance told Ada that she was afraid of Soles. She pushed past him and stalked in the direction of the collapsed camp, attended by a small cloud of her own camera drones. The rest of her team followed, acting equally nervous. Bodies were plainly visible, and the larger military drones of Soles' team hovered over them. Ada knew this pattern would appear very incriminating to Latore, and whoever was watching through the video feed.

"Um, Sergeant Soles?" It was Dr. Laurel on the line; she was about a hundred meters away but was walking over quickly. "I think you should give us back some of the drones. And my--one of our systems has excellent tactical support built into it."

"You want me to trust our lives to an experimental program, Dr. Laurel?"

"I'd bet my own, Sergeant." She emerged out of the ice fog, her stance indicating that she was not at all intimidated by Soles. "Besides, our systems are... well, they're itching to investigate. They have... Well, they have some ideas. I think they can help."

Soles threw up his hands. "Why not? Let's see what they can do."

"I'll put Ada on the line with you," said Laurel, and suddenly Ada found its list of conversational partners had grown to encompass the entire human team.

Evidently Alan had gotten control as well, because their previous tug-of-war suddenly began again. Alan had commanded some of the drones to back away from the wreckage. Ada agreed with that decision, and now realized that they did have common ground after all. The drones, and the environment they were embedded in, were that common ground.

One of Alan's drones was nudging a corpse that Latore was walking toward. Soles groaned. "Laurel, dammit, what is that thing doing? I'm overriding you--"

"Wait!" shouted Melko. "That one's mine. Just give me a--" Soles overrode Melko's control and sent the drone spinning away, just as Latore reached the body. She flung out her arms and began speaking loudly to her drone-cameras.

Melko was running toward the scene. "Melko, stay where you are," said Soles, but he was distracted as two other drones, one of Ada's and one of the Other's, had begun digging in a snowbank well on the other side of the site. Soles stopped and turned in a circle, looking confused.

"Wait, Sergeant, hear us out!" Melko puffed his way up to Soles. Latore was in heavy dialog with her team, waving her arms and pointing at the carnage. "Alan found something! The bodies. They're frozen."

Soles stared at him. There was a long silence. "Unless I miss my guess, Dr. Melko," Soles said at last, "this is Antarctica. Of course they're frozen."

Melko shook his head. "It's just thirty below out here, and the explosions happened just a couple hours ago. Alan got suspicious that journalists should be showing up--said it was 'too convenient' and decided to estimate time-of-death for the men here. Brilliant idea, because when the drones did a thermal check on the bodies, they found they're frozen through."

Soles hesitated. "Are you saying they wouldn't have had time to freeze solid yet?"

"Exactly! It's damn cold out here, but it's not <u>that</u> cold. And they're in parkas and they're on the ground, partially insulated by the snow."

"What about cause of death?"

"There's trauma consistent with a cluster-bomb attack, but Alan thinks it might be post-mortem."

"And the explosions? Hell, why am I asking you?" Soles sent a private query to Alan. She reasoned out what they might be discussing:

even without satellite communications, Ada had access to a local database of bomb blast patterns and presumably, so did Alan. Even Soles' tactical assistant carried terabytes of such useful information, as well as programs and tutorials to make it usable in the field.

Having anticipated what he wanted, Ada did a quick analysis and sent it straight to him. He grunted in surprise, looked around at the hovering drones, then focused on the images in his HUD again.

"Huh," he said. "That's funny." The shrapnel fields were perfectly circular.

"Sergeant Soles, this is Ada," Ada now said to Soles. He started, again glancing around. "If Latore's team is transmitting imagery off-site, some third party is almost certainly conducting the same blast analysis as we just have. The results are consistent with a U.S. missile launch from our Marie Byrd base."

Soles swore. "How do we shut this down?"

"Our chain of attestation can disprove that hypothesis."

Soles barked a laugh, then strode back to the journalists. "Ma'am, I can prove that we're not the ones who blew this place up."

Latore looked at him archly. "And how are you going to do that?"

"Actually, *you* can do it. You see, I wear a body cam. So do all my men, and those two scientists. All our drones have cameras too. Every one of those cameras takes a picture every three seconds. The pictures get encrypted and uploaded to an," he slowed down to pronounce the words properly, *"attestation blockchain* on the internet."[5]

Latore stood still for a moment, as the wind whipped snow around them. Ada shifted its focus to two of Soles' men, who were rolling stones away from the collapsed mine entrance. It shifted back when Latore said, "Go on."

"I can't show you the photos directly," Soles told her, "'cause they're U.S. military property, but the blockchain we load them into is public." Public, distributed, pseudonymous and beyond the reach of government or military manipulation, because it used the same unbreakable algorithm as the original distributed app, Bitcoin. "Each encrypted image gets

[5] https://www.provenance.org

timestamped and labeled by GPS location," he went on. "So each one can be cross-referenced with others from the same location and also compared to its own preceding sequence. Each one is proof of the next one in the chain, right?" The blockchain guaranteed the provenance of the images.

Latore conferred with one of her companions, then turned back to Soles. "So how can I look at this blockchain of yours?"

"Well, we have a bit of a... complication." Visibly uncomfortable, Soles told her that their communications wasn't working. She guffawed in disbelief, but at that moment one of his men at the mine entrance called in. "Hang on," he said, putting a hand to his ear reflexively. "Ha! No shit?" He glanced up at her. "Come with me, Ma'am. I have something to show you." Without waiting he trudged through the deep snow to the collapsed entrance.

"--No mine!" one of his men was shouting to a third who'd just arrived. "Look! It goes back five feet at most. And the digging equipment, it's not even cold-rated. There's no block-heaters on the battery packs, the tracks are all rusted out... The equipment looks like it's been sitting out in some rainforest for twenty years."

Latore clambered up the rocks to look through the gap Soles' men had dug in the rockfall. From Ada's drone perspective it was now obvious that the entrance was a fake, just a divot in the side of the rock face.

Latore held out a hand imperiously, and Soles helped her step down. "What were you saying about a communications problem?" she demanded.

"We're cut off," he said, "but that doesn't mean we couldn't continue the chain of attestation. If that happens the system just automatically adds them to a local sidechain. Sidechains allow blockchain transactions to be done 'on the side,' in isolation from the main chain of a system such as Bitcoin.[6] If you'd do me the favor of synchronizing our sidechain with the main USAF one, we can use to it prove that *this*," he swept a hand to indicate the scene, "wasn't done by *us*."

Again she spoke to her people; one thought Soles was trying to hand them a piece of malware. "What would be the point?" she laughed. "We've already sent out our report."

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[6] See https://www.blockstream.com/sidechains.pdf for more information

Across the valley, another of Ada's eyes saw the man shrug. "I've heard about this attestation chain thing," he said in English. "The Hague Court has an interface, it'll let us query the chain for violations of international law."

"Rocket launches, that sort of thing?" said Latore.

"Yes."

All military data was either quantum encrypted or, like the attestation blockchain, used fully homomorphic encryption. Homomorphically encrypted files like today's chain of attestation could be analyzed by untrusted third parties, who could analyze the images and send back the results, without ever actually decrypting the files or seeing the results themselves.[7] Everything Soles and his men had done today was there in an interlinked set of image sequences that existed, autonomous, incorruptible and unhackable, on the Internet. Its contents could be searched for specific events--such as rocket launches from Marie Byrd--but would remain encrypted and thus secure at every step of that process.

Back at the Marie Byrd base, normal ops were conducted under similar chains of attestation. The base security cameras contributed, as did external cams, cockpit cameras, voice recorders, black boxes and body-cams. Every moment of the day was recorded, publicly available for scrutiny yet with full security in place to prevent abuse. You could ask for quorum-slices across the federated byzantine network that all of these systems contributed to, and prove what had really happened at a given place and time.

During all of this Melko had been heavily in dialog with the entity behind Ada's blindspot. Now he waved at Soles again. Soles told his men to figure out how to copy the attestation trail from their own network to Latore's then trudged over to where Melko was standing in a cloud of flockers. These had all been under Alan's control, but Ada negotiated the release of a couple and so was present when Soles reached Melko. Through a flocker's eyes Ada saw that Melko was holding one of the little catalytic hand-warmers they all carried. He had it balanced on the palm of his glove and he and Laurel were gazing at it in fascination. "What now?" said Soles.

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[7] https://en.wikipedia.org/wiki/Homomorphic_encryption#Fully_homomorphic_encryption

"Look at this!" Melko held out the heater. It was oval, metal, sized to fit in the palm of a human hand. Right now it was unblemished except for a few white snowflakes scattered across it. "See?" said Melko excitedly.

"No, Dr. Melko, I do not see."

"Watch!" Melko reached down with his other glove and scooped up some snow. He scattered it on the heater and, of course, it melted. But not all of it.

"What are those?" Some of the flakes just stubbornly sat there as the rest turned into tiny beads of water. Melko grinned at Soles triumphantly.

"It's smart dust.[8] We think. The whole valley's saturated with it. It's what's been causing the interference with our systems. It's designed to do that--but it's also smart enough to discriminate between military and civilian signals. It's letting Latore communicate--but not us!"

While Soles swore, Ada tried to calculate the size of the smart matter field. As Soles said, "We have to get out of here," Ada realized that Alan's perspective, while different, might be useful. There might be a way to get at it...

"Bring that stuff," said Soles as he headed back to Latore's group. Her expression suggested she was even more unhappy than she had been when she thought she'd come across a massacre. "We uploaded your sidechain," she said. "It matched the official one. And unless every single camera and device in the United States military has been subtly altering its data for months now just to hide two rocket launches today... it's on the level.

"You *didn't* blow this place up. Your men told us about the temperature of the bodies, so we checked ourselves and Jorge did some calculations. These bodies were here long before the explosions. And you know, the mining company, they were so insistent we come here *today...*

"We've been tricked. All of us."

At that moment Ada felt a shift in the interference surrounding them. The smart matter field was adjusting itself, changing its coverage frequencies.

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[8] https://en.wikipedia.org/wiki/Smartdust

One of Latore's men swore. "We just lost our connection!"

The smart matter wasn't passive. Apparently, there was more than one other tactical AI here, and this third one was not friendly.

"Sergeant," said Ada, "I believe it is time we got out of this valley."

#

Di Paolo appeared at the virtual conference table. "Perry, I need an answer. By 'I' of course I mean Washington. Unless you can tell that this little mining disaster you're investigating means something, I'm going to have to tell our people that Esperanza has been taken over by a hostile force, but that we know where their command center is--that ship at the dock. We've run thousands of sims, we know how to take it out. Just tell me know there's no trap-doors here."

None of it felt right, but Perry had no answer. He was about to say, "go ahead," when the monitors around him flickered. The wall screens, the conference table holograms--all of them had been a jumble of images and talking heads a second ago. The various members of the pickup game, human and nonhuman, and the data feeds and analysts they were working with had been arrayed around Perry, and he'd felt he was keeping up. Now, just as he realized he was feeling overwhelmed, and as Di Paolo waited, all those images had been replaced with one face.

It wasn't someone he knew. It wasn't anybody human, because its features kept shifting subtly, as if trying to settle on a gender, an age, an ethnicity.

"Who're you?" blurted Perry.

The face smiled at him. "The entire pickup game, including its ombudsman and all its various participants, has become too complex for its human players to keep track of *as an activity*. Your minds are optimized to understand complex phenomena as narratives or as people. We used Chernoff faces to take advantage of your visual cortex's optimizations around facial recognition; in the same way, the ombudsman has decided to use your optimizations for dealing with other people to make the results of the game clear to you.

"**The ombudsman has generated a new liaison**, one that stands for, or is a mask for, the distributed cognition of the whole game. I am that liaison. I also include the ombudsman. You can speak to me now as if I were a person, and I can filter your requests and comments to the appropriate human, AI, sensing service or reference in the game.

"You can call me *the Situation."*

#

"Approaching the mine site," said Gapenne. "If they were there they should be responding by now." She was in full virtual reality rig again, commanding the same hybrid she'd used to drop off the research team earlier in the day. Outside her office, the sun would be setting; in Antarctica, it had merely circled halfway round the sky, shadowing the landscape below from a different angle than the last time she'd overflown it.

The Antarctican commander, Perry, had asked for her to fly the bird again. He wanted the same eyes on the scene as before, and though she couldn't say why, Gapenne was glad to feel useful.

She could see the blown out quonset huts now, vehicles strewn around the fringes of snowy ruts. There were tiny dots that her visual analytics was telling her were people. The same analytics were having trouble with the rest of the scene, though.

"Sir," she said. "Something's strange."

"What is it?" The voice in her ears wasn't Perry's or Brinks'. In the last few minutes before she'd put on her headset, a new person had joined the PIE, dominating the displays and talking, it seemed, to everybody at once. The voice sounded like this unknown officer.

"My optics are thrown off by the blowing snow, but I should be able to compensate on other frequencies. But the readings I'm getting are... weird."

She flipped to a terahertz view of the valley, and was rewarded with an eyeful of psychedelic shifting color. "Damn."

"I see that," said the voice. "It seems to be interference of some kind."

"The things is," she said, "the hybrid's not seeing the quadcopters. If they're not there, where are they? Where's our team?"

"Perhaps they've left the valley."

"No. I can *see* them. I mean visually. But my systems can't."

Gapenne enjoyed looking around when she flew. One of her favorite flight paths took her over Shark Bay in Western Australia, because the bay lived up to its name: if you looked down at altitude, you saw brilliant turquoise water and thousands upon thousands of little black dots:

sharks. She'd also done search and rescue and was very good at recognizing objects on the ground.

She remembered what the quadcopters had looked like from the air as she ascended after dropping them off. "I tell you I can see 'em, clear as--well, whatever it is down here."

She also saw something else. "The roads, the roads!" she shouted. "I knew there was something funny about them. They're just a few ruts, they don't look like they've been used for weeks and weeks." The whole area around the Marie Byrd base was crisscrossed with packed desire lines made by wheel, track and foot, but while all those forces should have been at work here during the mine's construction, there were only a few tentative threads joining the structures. "It's a fake!"

There was a pause. "Do you know what chaff is?" asked the voice.

She laughed briefly. "Granddad was in the War. He talked about how they'd eject long streamers of tin foil to screw up radar. Wait... you think..." She looked down more carefully, playing with the frequencies of her optics, radar, and LIDAR. There did seem to be something--a bunch of smears radiating from the thin roads. They looked like the patterns the commercial snow-makers at a resort would make as they threw powder...

"I'm going down," she said suddenly. Gapenne waited, expecting to be told not to. But the countermand didn't come. Suddenly grinning, she put the hybrid into a dive that would require her to turn the fans on full during the approach. "Hang on boys," she told the quick response team in her hold, "it's gonna get rough for a couple minutes."

Time to blow away the chaff.

#

The drones were dancing.

Sergeant Soles hadn't noticed. "I can see her, but I can't get a signal through," he was shouting into his comms. His eyes were fixed on the sky, where a hybrid airship was circling. He had just tried piggy-backing a signal through the journalists' satellite uplink, but the 'snow' was now blocking that too. The white powder had some intelligence. Ada and Alan were trying to analyze it, but their thinking styles were so different that they couldn't communicate directly. Instead, they were watching one another interact with the environment, through the drones. Hence, the dance.

"Soles!" The Sergeant looked down to see Melko and Laurel waving at him. They were huddling with Latore while her people brought up their

skidoos. The plan now was to make for the ocean and the trawler, and hope they could pick up a signal there.

"It's Alan and Ada," Melko said as he strode up. "They've started working together!"

Even an hour ago, Ada knew, Soles would have just stared at Melko for making one of these pronouncements. Now he said, "What does that mean?"

"They've found some common language," said Laurel. "Now they're combining forces to hack into the 'snow.' If they can do it they might be able to stop the jamming. They might also figure out who's behind this. But Ada says in order to do that, they'll need control of all the drones."

"Well, you can have 'em!" The remaining drones stopped their aimless search patterns, and began sweeping about purposefully.

"What am I looking at?" asked Soles.

Laurel grinned. "You can ask her yourself," she said. "She's on Channel fourteen."

Soles added the channel into his comms. "Hello?" he asked.

Ada and Alan did a quick bee-dance, combining Ada's understanding of the scenario with Alan's action potentials. "Hello, Sergeant," said their combined voice. "We've hacked into the nanotech chaff. Apparently this entire area, and your presence in it, is being used to convince the world that the United States is willing to use force to protect its territorial claim in Antarctica. This valley is a honey-trap, and we've fallen into it."

Soles swore, and turned to tell his men to moonwalk out of the valley--*now*--to try to get a signal-

--And suddenly the hybrid airship was right overhead and settling over the camp in a hurricane of whirling snow.

#

"Perry, I need more than just your feeling that 'something's not right here,'" said Di Paolo. "If Esperanza's not really under attack, then what is really going on here?"

Perry blinked at him. "That's the question," he said. "You got it, sir."

"What did I get, Perry? You're not making sense."

Perry turned to the Situation. "Why would someone want the United States intervene somewhere in Antarctica? Forget about Esperanza. Why would they want us to do it, *anywhere?*"

#

On the far side of the world, Carter laughed at the Situation's question. "Well, that's obvious, isn't it?" he said.

"I'm up here helping negotiate the new UN Treaty on the Peaceful Uses of Outer Space. It's a lot like the Antarctican Treaty. In fact, they're so similar that the one's been used as a precedent for the other. What, you didn't know that?"

On his laptop screen, the Situation, which had settled into a Latin-American face, shrugged wordlessly. Carter laughed again.

"Treaties are broken by actions," he said. "The Bolivarian Union broke the Antarctic Treaty when they annexed the peninsula. That was an open invitation to everybody else to do the same, but at the time, the other powers restrained themselves. Now the United States has actual military forces offshore, though not actually on the ground. I <u>assume</u> Marie Byrd isn't an actual military base?" The Situation nodded.

Carter said, "The instant you put boots, ordnance, drones, *anything,* down there, you're either breaking the treaty yourselves, or making a statement of support for somebody else who already has. It's an opening, an opening of the floodgates, and not just for Antarctica. You blow the Antarctic Treaty, you also blow up the Space Treaty..." He stopped, staring abstractly into the distance. "Maybe..."

"Thank you," said the Situation. "That's what I needed to know."

#

Melko reached for Laurel's hand as, gasping, they dodged out of the way of the hybrid's backwash. The airship was acting crazy, slewing back and forth across the mine site. Damnit, it was destroying all the evidence, covering the bodies, knocking down the last standing walls of the quonsets--

"I have a signal!" shouted Soles.

--And blowing away the chaff. Melko looked at Laurel, and suddenly they were laughing. She gave him an unexpected hug, and then they were all business.

"Adalan," said Laurel, "upload your findings immediately."

"I've been asked to join an intelligence pickup game," said the AI. "It's an urgent request, pertaining to what's happening here--"

"Yes, do it!" they shouted together.

About a kilometer down the valley, the hybrid was settling onto the snow in a vast, swirling cloud. Soles and his team were running toward it.

Melko sat down on the tread of a bulldozer and watched them go, laughing. "What the Hell is going on?"

A new voice in his ear said, "I believe I can answer that."

#

"We have confirmation," Perry told Di Paolo. "From our ground team at the mine site, and our other assets. It is imperative that we do nothing. We must not take any military action, especially not at Esperanza. It's all been a trick to get us to react. We've been baited."

The conversation was three-way now: he, Di Paolo, and the Situation. Behind them a massive cyber, HUMINT and analytic operation was continuing to unfold; the Situation was closing in on who was responsible for the deception, analyzing the nanotech chaff recovered from the mine site, interviewing the journalists, following multiple trails. Here and now, though, there was just the three of them.

Everything Perry knew was being laid out before Di Paolo in his office. Sometimes the Situation spoke to both he and Perry, and sometimes Perry could hear it and Di Paolo murmuring together without him. He smiled, glancing around to find Eden and Morris watching him.

Perry blinked and took another look. Aside from those two, there was only a scattered handful of personnel actually in the PIE. Naturally--the Marie Byrd base was small, isolated--the last place on Earth anybody would want to get posted to. Today, though, for a while, the place had been a cyclone of activity.

"I can work with this," said Di Paolo suddenly. "I don't have to know who it is exactly who's pulling the strings to know that our strings are being pulled. Someone wants the United States to make some kind of intervention in the Antarctic--<u>any</u> kind of intervention. They tried to make it look like we'd laid a violent claim to Marie Byrd Land, but we've proven otherwise. We'll ram our chain of attestation down their throats. Whoever it is, they're also trying to force our hand when it comes to relations with Antártica. They'll probably try something else if that doesn't work. Maybe it's Antártica itself, trying to broaden its international recognition. Hell, it

might even be Norway! They don't like the idea that the Arctic sovereignty negotiations are likely to turn the Arctic Ocean shelfs into a UN-governed commons, 'cause that would set a precedent for their claims down here.

"Doesn't matter. Gentlemen, we are not going to bite. "Perry, bring our birds home. We're going to wait this one out.

"Good job, Major General," he added. "It could all have gone sideways if you hadn't kept your teeth in the mine thing."

"Thank you."

"So: flesh out the forensics teams at the mine site. We'll work with those journalists to get their story. They'll be on the news tonight. Nobody's going to hear about you and me, but--" Di Paolo grimaced--"that's part of the job."

"Understood."

"Good. Keep me posted."

Di Paolo rang off. That left Perry in a suddenly quiet room, with his own base personnel, and gazing down at him from the wall screens, the Situation.

"Morris," he said, "those kitchen supplies you tossed out of here earlier.

"Did they include any fresh coffee?"

#

Soles looked into one of the cameras in the hold. "Back so soon, Gapenne?"

"How'd you know it was me?" Her voice over the coms was barely audible; the airship's hold was full of buzzing drones jockeying for positions to land on the stack-frames. Two scientists and a team of South American journalists were shouting to be heard over them as, behind it all, the door to the hold levered up.

"It'd have to be you. You're the only one of us who was having a good day."

Louise gave a staticky laugh. "And now I get to haul your guys' asses home. That's got to count for something."

At that moment the doors finally closed, the last drone shut off its engines, and suddenly everybody was looking at Soles as he yelled at the intercom. "Um," he said more quietly. "We're just glad you're here. Loved that whole backwash thing, by the way."

As the airship lifted the journalists fell silent; they were busy filming out the small windows. Melko walked over to see what they were so interested in.

The entire mining camp was laid out like some macabre diorama, complete with miniature bodies. White-suited figures were slogging towards these from three other airships that had just landed a little down the pristine snow-plain. "Forensic units," he said, loudly enough for Latore to hear him.

Latore glanced over. She'd thrown back her hood, unwoven the big wool scarf that had been over her mouth, and shoved her ski goggles back. "How do we know they're not here to destroy the evidence?"

"Have we confiscated your recordings?"
She barked a humorless laugh. "We already uploaded them."
Melko shrugged. "Whatever."

"Seriously, though." Latore held out her hand for him to shake. "I don't like being used as a dupe. You helped stop that happening. And our story got a lot bigger than any of us expected."

He shook, grinning. "Who are Alan and Ada?" Latore asked suddenly.

Laurel had been listening. "Off the record?" she said. Latore nodded impatiently. They all knew that the words, and her nod, were being added to the chain of attestation. She couldn't cheat on that. "Artificial intelligences," said Laurel. "They're basic minds that have a very narrow focus on understanding one thing. We were testing them in the field, then all this happened. Now they've been turned into qualia agents."

When Latore looked blank, Melko added, "Like the basic minds we all have in our cerebrum. They don't just passively process sensory information, they think about it and make all kinds of inferences before passing it up the chain to the parts of the brain that we're conscious of. At some stage in evolution those modules were the minds of the organisms we evolved from. New brain systems got built on top of them over millions of years, so they're no longer complete minds, but they still perform their essential functions. They just do it in lockstep and without having to be self-aware.

"Same thing just happened to our AIs," he said ruefully. "While we were cut off they were acting alone, but now they've been recruited as part of a larger mind."

"--And, that's all we can say," added Laurel with a sharp glance at him. Melko shut up, though he was bursting to describe how it all worked--the intricate process by which many different agents and actors could combine to form a distributed, extended consciousness, one that had evolved in realtime to deal with the exact ambiguities of today's situation. Most of all, he wanted to tell her about the revelation he and Laurel had come to through this whole experience--namely, that they would never find any common language for their AIs that was better than the physical world itself. *The environment* is *the metalanguage,* he wanted to tell Latore; but Laurel continued staring at him, and he bit his lip and shrugged.

Soles saved him by coming over, and he and Latore launched into an excited recap of the day's events. Melko drew Laurel aside.

"You know what I think happened?" he asked her.
"It was Norway," she said indignantly. "They want to keep Queen Maud Land."

"Oh, that," he said, dismissing the geopolitical picture. "I mean with Ada and Alan. They were self-aware for a while, but now they've been supervened. Something else is emerging and they're part of it. Maybe Alan's role is to daydream, make irrational connections and leaps of logic. Ada's the chess player, looking ahead at all the combinations. But they're parts of the same mind now."

Laurel was silent for a moment. She stared at the stacked drones, about to be deployed as journalists' eyes and ears and yet, somehow, still retain their functions as sensory organs for the thing Melko was describing.

"If there could be a meta-language for describing reality," she said at last, "life would already have evolved it. It's had four billion’s to do it. Our systems are only going to be able to make sense of each other if they use the physical world as their touch-stone. And when they do, like Ada and Alan... they can become bigger together than they are individually."

The Situation was nearing the end of its life. Both of them knew that its drives didn't include survival. As soon as it had sorted out the major threads of today's events, the temporary mind was going to unravel and dissolve back into the subsystems, the people, the databases. It would be gone within hours. Even this hybrid had been one of its sense organs, if only for a while.

Melko reached out to touch the airship's hull, feeling the faint vibration of travel. "I wish I could talk to it," he murmured.

"You did better than that," Laurel said. "You were part of it, for a while. We both were." But she smiled ruefully, for she understood what he meant.

-- End --

Appendix B. SDD Workshop Application Plans

Structured Dialogic Design (SDD) Workshops 2 & 3 - Outline

1. Workshop Deliverables

2. Design of Inquiry

- SDD2 Design Options Triggering Question
- SDD2 Qualitative Roadmap Relational Question
- SDD3 Actions Triggering Question
- SDD3 Action Plan Relational Question

3. SDD2 Workshop Plan

- *Symposium Schedule*
- *Structured Dialogic Design 2 Schedule – Solution Formulation*
- *Solution Domains, Portfolios, Qualitative Roadmap*

4. SDD3 Workshop Plan

- *Structured Dialogic Design 3 – Action Planning Day One*
- *Structured Dialogic Design 3 Action Planning Day Two*

5. Elicitation Processes

6. Stakeholder Challenge Conversations

1. Workshop Deliverables

1.1 SDD2 Deliverables

Narrative 3.0

Transcript of Symposium

Elicitation of Solutions

- *Solution Name & Statement*
- *Which Challenge is Addressed*
- *Scenario Example*
- *Indicator of Success*
- *Clarification Dialogue*

Clustering of Solution Domains & Composite Clusters
Ranking Importance of Solutions
Qualitative Roadmap
Solution Portfolios
Consensus Solution Profile
Superposition of Solutions & Challenges

1.2 SDD3 Deliverables

Narrative 4.0

Elicitation of Actions

- *Action Statement*
- *Solution per Action*

Action Groups

Ranking of Importance of Actions

Action Plan

2. Design of Inquiry

SDD2 Design Options Triggering Question

“What are AFRL Third Horizon solutions (design options) addressing Situation Representation for autonomous response to the unexpected in “pick-up” games enabling a common technical vision for Strike, EW/Cyber & ISR?"

SDD2 Relational Question (for Qualitative Roadmap)

Is there a capability of A which is necessary for the function of B?

Action Plan Triggering Question - or -

Is there an advancement afforded by A which is necessary for the development of B?

Action Plan Triggering Question

SDD3 Actions Triggering Question

What actions can concentrate us on a **Focal Problem** which addresses the deep drivers of the far-term **Qualitative Roadmap**?

Where:

“Qualitative Roadmap“ means Qualitative Roadmap of Solutions for Situation Representation with Pickup Games in Autonomy?

“Focal Problem” means cultivation of near-term prototype, of technologies on a far-term trajectory, which is instrumented to provide proof-of-principle for Situation Representation specialists.

SDD3 Action Plan Relational Question

Is there at least one end-result of completing action A which is absolutely necessary to complete action B?

3. Structured Dialogic Design 2 Workshop Plan

Table 1

Table 1 - Symposium Schedule – Day 1: Morning

Agenda Item	Activity	Presenter /Facilitator	Min
1	Coffee with Introduction Activity		
2	Welcome	Kirk Weigand Sponsor	5
3	The Agenda	Peter Jones	5
4	The Scenario – Presented as a Dialogue	Avatar Karl Schroeder Steve Rogers	10
5	Discovery Themes & Challenges Narrative 3.0 Illustrated by Examples in the Scenario	Kirk Weigand	10
6	Challenges in Situation Representation as the Context of Inquiry *The Scope, Social Network, Distinctions, Language, & Meanings of SR using examples based on the Scenario to talk through*	Panel Dialogue of 4 participants with very different perspectives – Peter Jones	20
7	Solutions Trajectory Talk 1	External 1	10
8	Solutions Trajectory Talk 2	External 2	10
9	Solutions Trajectory Talk 3	External 3	10
10	Panel 1, 2, 3 Q&A	External 1, 2, 3	10
11	Break & Face-to-Face Introductions Activity	Peter Jones	30
12	Solutions Trajectory Talk 4	External 4	10
13	Solutions Trajectory Talk 5	External 5	10
14	Solutions Trajectory Talk 6	External 6	10
15	Panel 4, 5, 6, Q&A	External 4, 5, 6	10
16	Lunch – with Face-to-Face Introductions Activity		60
			260

Structured Dialogic Design 2 Schedule – Solution Formulation

Table 2 - Symposium Schedule – Day 1: Afternoon

Agenda Item	Activity	Presenter Facilitator	Min
1	Reflections on Discovery & Challenges in Autonomy	Steve Rogers	2
2	Agenda & New Seating	Peter Jones	5
3	Triggering Question Eliciting Solutions	Kirk Weigand	10
4	Silent Generation & Writing of Ideas on a Sheet	Peter Jones	5
5	Share Ideas with Partners (Groups of Three)	Peter Jones	3
6	Name Each Idea on a Separate Card	Peter Jones	
7	Individually Rank Ideas to Share First	Peter Jones	1
8	Round Robin Sharing of Names of Ideas (Five or more rounds)	Peter Jones	50
9	Note which Challenge #(s) Solution Responds to	Peter Jones	5
10	Silently Formulate an Example with respect to the Scenario for First Idea	Peter Jones	5
11	Share Examples with Partners (Groups of Three)	Peter Jones	10
12	Note indicator of success on back of each solution	Peter Jones	5
13	Distribute Table of Solutions		1
14	First Round Robin Clarification with Scenario Example and Indicator of Success	Peter Jones	20
15	Break with Face-to-Face Introduction Activity	Peter Jones	20
16	More Round Robins Clarification with Scenario Examples and Indicators of Success	Peter Jones	100
			242

Solution Domains, Portfolios, Qualitative Roadmap (Common Trajectory)

Table 3 - Symposium Schedule – Day 2

Agenda Item	Activity	Facilitator	Min
1	Face-to-Face Introduction Activity		
2	Agenda Check-In		5
3	KJ Clustering "Solution Domains" Seeded by Similarities from the Clarifications and Clustering wrt Discovery Themes in Parallel	Kevin Dye	20
4	Amending Solution Domains (Clusters)	Kevin Dye	30
5	Naming Solution Domains (Clusters)	Kevin Dye	10
6	Two Groups Sorting Solutions into Discovery Themes and Challenge Topics for Cross Reference	Kevin Dye	30
7	Break – Face-to-Face Introduction Activity	Kevin Dye	20
8	Distribution of Solution Domains (Clusters)	Kevin Dye	1
9	Voting	Kevin Dye	10
10	Structuring (Share Intermediate Structures Hourly)	Kevin Dye	110
11	Lunch with Face-to-Face Introductions		60
12	Structuring (Share Intermediate Structures)		70
13	Four Small Groups Develop Solution Portfolios		20
14	Present Solution Portfolios		20
15	Consensus Portfolio (Composite Options Profile)		10
16	Cross Impact of Solutions on Challenges		5
17	Erroneous Priorities Analysis		5
18	Focal Problem Small Group Deliberations		40
19	Small Group Focal Problem Summary Reports		10
			476

4. Structured Dialogic Design 3 Workshop Plan

Table 4 – SDD3 Workshop Schedule – Day 1

Time	Activity	Facilitator	Min
1	Face-to-Face Introduction Activity		
2	Agenda		5
3	Triggering Question Eliciting Actions		10
4	Silent Generation of Actions on a Sheet		5
5	Develop a Short Name for Each Action on Forms through discussion i groups of three		15
6	Round Robin Statement of Actions		50
7	Identify which Solution(s) and Indicator of Success the Action Addresses on Form		5
8	Clarification of Solutions with Breaks		120
9	Lunch		60
10	Clustering Action Groups by Similarity to Each Other		60
11	Voting		10
12	Structuring the Action Plan with Breaks		140
			480

Table 5 – SDD3 Workshop Schedule – Day 2.

Time	Activity	Facilitator	Min
1	Face-to-Face Introduction Activity		
2	Agenda		5
3	Continue Structuring the Action Plan		120
4	Break		
5	Interpretation of the Plan		10
6	Develop SMART Objectives for Key Actions in small groups		30
7	Develop tasks/checklists/Work Breakdown Structure for Key Actions		30
			210

5. Elicitation Processes

Elicitation Form for Solutions in SDD2

- Solution Idea (Sentence Length)
- Short Name (One to Four Words)
- Rank
- Challenge(s) Responded to
- Indicator of Success

Elicitation Form for Actions in SDD3

- Action Idea
- Short Name
- Rank
- Solution(s) Responded to
- Indicator of Success (From Solution card)
- Doran's SMART Objectives Guidelines (on reverse side)
    - **Specific** – Make objectives very specific or list several more specific actions
    - **Measurable** – use the Indicator of Progress from Solution(s) addressed as baseline but make more specific/quantified if possible,
    - **Assignable** – identify the specific people that will do this work,
    - **Realistic** – determine what results can reasonably be expected given constraints,
    - **Time-Related** – specificity as to when the results can be achieved.

6. Stakeholder Challenge Conversations

The matrix in Figure B-1 shows the cross-connections between stakeholders identified for invitation to the DD workshops. The red boxed cells indicate up to 28 paired or small group conversations that we proposed to develop the domain knowledge linkages between stakeholders knowledgeable of deep driver Challenges. The expectation for connection is based on the requirements a particular Challenge entails with its dependent issues or related challenges. The numbering starts at the most “dependent” Challenges (those that are most influenced by others) and works towards the deep driver challenges, then back.

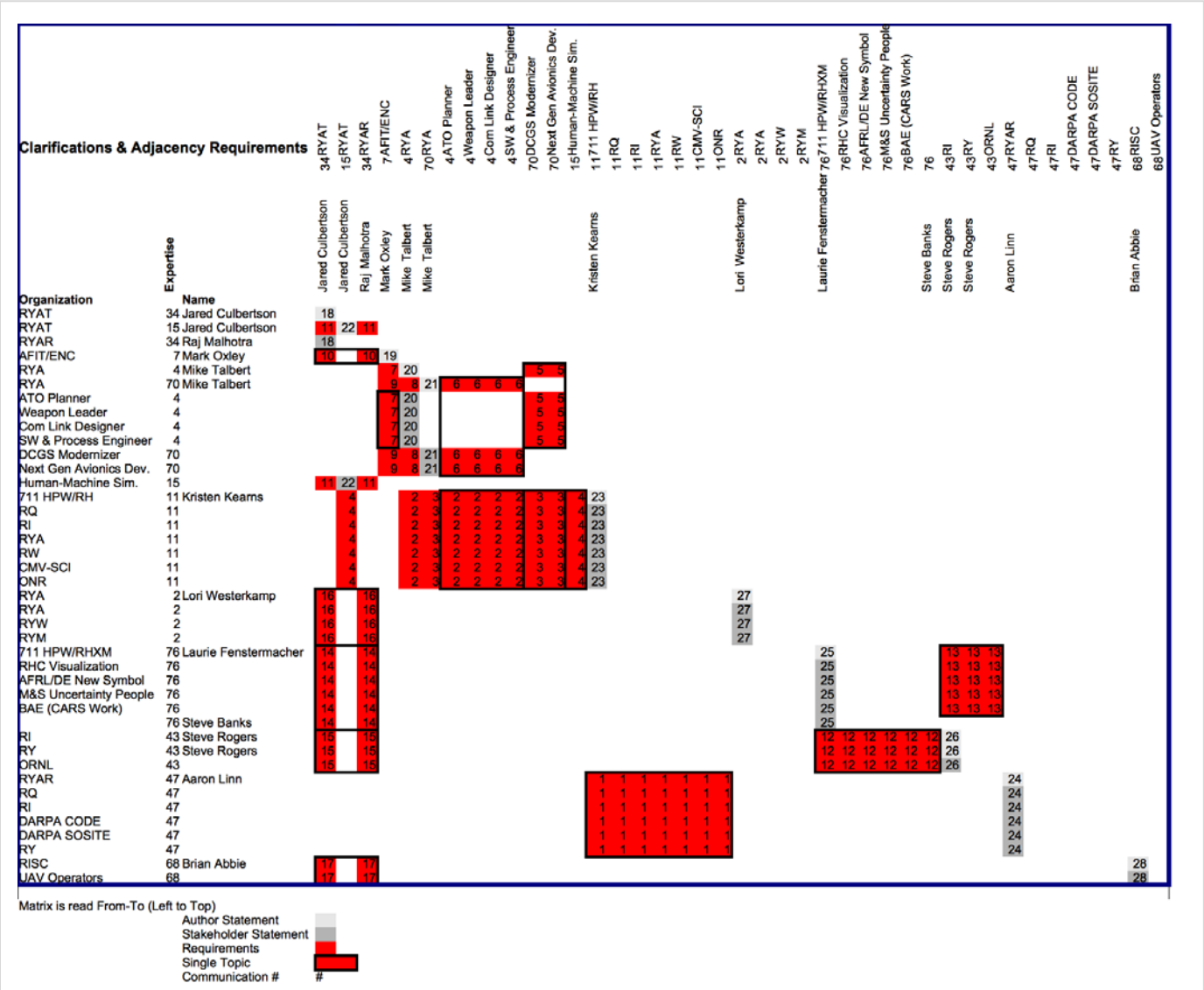

Figure B-1. Stakeholder Challenge Conversation Matrix

Stakeholder conversations were to be orchestrated by the DDI team by email contact to inform participants of the process, allowing them to conduct a semi-structured discussions, similar to a cross-interview, on their own time via phone or email prior to the workshop.

Appendix C. Stakeholder Analysis

1. Stakeholder Analysis Criteria

An extensive stakeholder analysis was conducted to ensure the selection of particpants in the planned two engagements would be sufficiently robust. Structured Dialogic Design is based on Ashby's (11) Law of Requisite Variety applied to social systems, wherein the goal of participant variety is to ensure requisite knowledge and actionability with respect to challenges and recommended solutions and actions.

The stakeholders selected for invitation to the SDD2 workshop and envisioned for SDD3 were identified based on their association with the challenges raised in Discovery and SDD1 workshop.

Requisite Variety applies to the selection of people associated with a challenge based on their knowledge about the area, their influence in the field, or their power or decision capacity over it. We also use a heuristic known as "5I's" for the five traits associated with stakeholders beginning with the letter "I".

- **Intelligence** - Stakeholders who have knowledge and information regarding the problem situation. This includes people who have experience. .
- **Impact** - Stakeholders who will likely impact or be impacted by decisions and/or when resolving the problem. It will also include stakeholders who may have power of decision on issues to be resolved and also people who may have the decision power to veto recommended changes.
- **Implementation** – Stakeholders who are likely to be involved on the implementation of the resolutions/future research inquiry
- **Interest** – Stakeholders who have an interest on the problem situation.
- **Involvement** – Stakeholders who have been involved in previous work toward resolution of the problem situation.

Two graphical tables are shown that represent a matrix of suggested stakeholders for participation in the two SDD workshops. The mix of official roles, disciplinary backgrounds, organizations and research interests are shown.

Table 7 provides a list accounting for the AFRL stakeholders believed to be the most relevant participants for the multi-disciplinary concerns of situation representation for human-machine team, as signified by the Triggering Question.

Table 8 represents the formative list of non-AFRL stakeholders, including Department of Defense, academic researchers, and independent think tank participants believed to be the most relevant to the focal Issues of concern.

Table 6 – Matrix of Proposed Stakeholders, AFRL

Candidate	Role / Background	Organization	Domains / Specialty
AFRL Core			
Steve Rogers	Sponsor - Observer	**RY / RI jointly**	Sensor and system engineering
Raj Malhotra	Participant (first time SDD)	**RY**	Foundation of Autonomous Sensing, Sensor engineering
Jared Culbertson	Driver owner (C34)	**RYAT**	SW Engineering, Algorithms
Lori Westerkamp	Tech advisor & sponsor level	**RYA**	Sensor engineering
Laurie Fenstermacher	Key HF Contributor	**711 HPW/RHXM**	Anthropology, cultural models of social behavior
Kristen Kearns	Autonomy initiative lead	**711 HPW/RHXM**	
Aaron Linn	Sensor eng / Y / EE	***RYAR***	
Mark Derriso	HF / Mid / EE	**711 HPW/RHC**	ISHM Product Lead
Mike Talbert		**RYA / RHX**	
Mark Oxley		**AFIT/ENC**	Systems/Engineering education
John Raquet		**AFIT/ENGE**	Systems/Engineering education
Brian Abbe		**RISC**	
Steven Loscalzo		**RISC**	Computer Science
Chris Reuter		***RYWA***	
Bruce Clough		***XPT***	
John Cherry		***RYAR***	
Robert Patterson		**711 HPW/RHXM**	Cognitive psych & models of reasoning
RI Senior Advisor?		**RIS**	

Table 7 – Matrix of Proposed Stakeholders, non-AFRL

Candidate	Role / Background	Organization	Domains / Specialty
Other DoD / Gov			
JC Leday / James Crowley	**Program Manager**	**DARPA**	CODE & SOSITE programs
Joe Lyons		**PC-PADx**	
Colin M., LtC	**DCGS / ISR User Rep**	**AFISRA - 25th AF**	ISR Wing / Intel
Recommend	**PCPAD User Rep**	**AF - DCGS**	
Bill McQuay	Sr. Advisor (Ret)		
Wayne Hughes	Ext senior advisor	**CRUSER / NPS**	
Alan Schultz	Adv autonomous systems	**Lab Auto Sensing Res (LASR) NRL**	
David Aha		**NRL** (Co w/ Raj M)	
Ethan Stump ?	Researcher / Robotics & auto sensing	**ARL**	
Bob Grabowski / Jessica Rajkowski	Autonomy system engineering / integration	**MITRE**	Autonomy system engineering / integration
Bill Clancy, Robt Hoffmann	Ext advisor / Adv modeling complex systems	**IHMC**	Multi-agent sim / Human system modeling
John Flach	Ext advisor / HF & control theory	**WSU**	Human Factors / Cognitive Systems
Dave Woods	Ext advisor / CSE	**OSU CSEL**	Cognitive Systems Engineering
Jerome Busemeyer	Cognitive psychology professor	**IU Psychology**	Quantum math, Decision Research Lab
Kenneth de Jong, Sean Luke	Ext advisors / ? / Adv modeling complex systems	**GMU**	Autonomous Agents & Multiagent Systems
Peter Asaro	Ext advisor / 65 / Human & social behavior	**Rutgers / ICRAC**	Situated action theory, Ethics in autonomy
Ron Arkin	Ext advisor / 55? / Autonomy	**GA Tech**	action-oriented perception for mobile robots and unmanned aerial vehicles, robot ethics
Lt Col Craig Perry	Cyber/Info ops Futures, Megatrends	**JIOWC**	
Sterling Wiggins	Close advisor / 50 / HF & CSE	**Aptima**	Cognitive Systems

2. Comprehensive Stakeholder Analysis

Stakeholder organizations and individuals were elicited from the Autonomy Steering Group (SDD Participants). This section offers views by Challenge and their authors and nominated stakeholders, and by the *deep driver* of the system of challenges. It also provides an alphabetical index by Nominated Stakeholder Organization. It concludes with a cross-reference to a recommended set of participants based on an analysis of diversity of perspective and presuming a workshop of less than 30 participants.

Note “Stakeholder Nominations” were defined by the participants in the Dec 15, 2014 Autonomy workshop. “Stakeholder Recommendations” were defined by the DDI session facilitators.

The sections are as follows:

A. *Participant Stakeholders*

B. *Author-Nominated Stakeholders per Challenge*

C. *Stakeholders in the Deep Driver & Similar Challenges*

D. *Author & Stakeholder Organizations by Challenge (Diagram)*

E. *Index of Stakeholder Organizations*

F. *Cross Reference Nominated Challenge Stakeholders to Participant Recommendations*

2.1 Participant Stakeholders

The primary set of stakeholders for Autonomy Discovery included the particpants in the SDD1 Collaborative Foresight workshop, and their direct organizational affiliations. These are specified in terms of the contributors to the influence map, as the subset of participants whose challenges contributed to the influence map shown in Figure D-1.

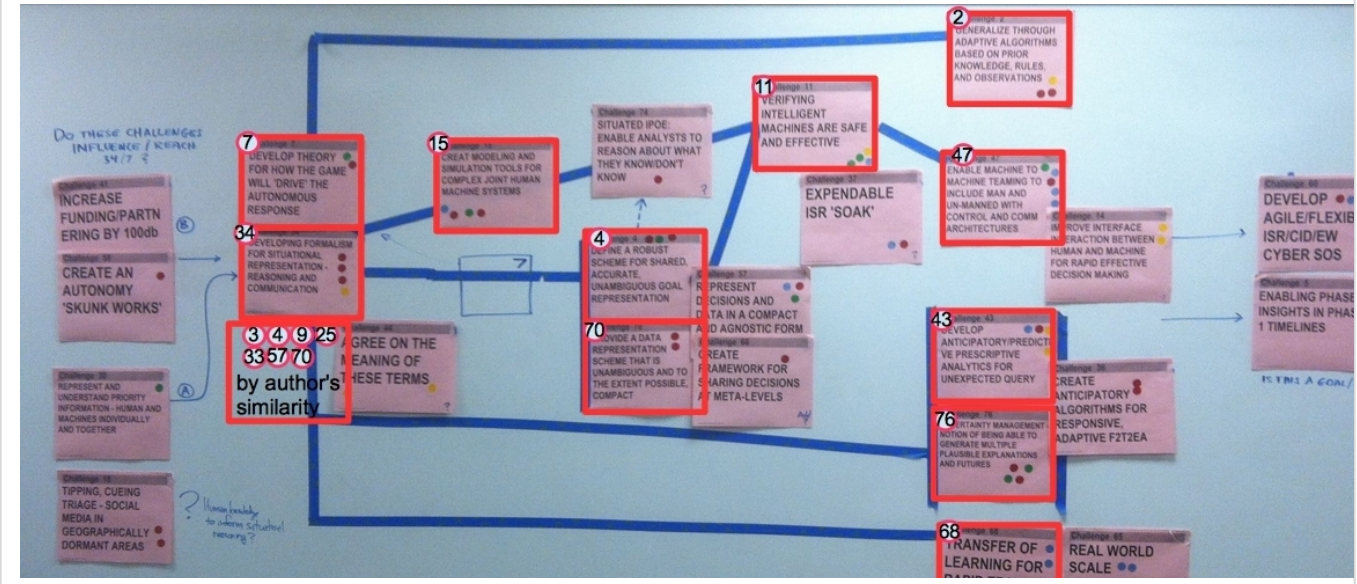

Figure C-1. SDD1 Influence Map with references to Challenge numbers.

Challenge Authors / Organizations by C-Number in the Structure of Challenges

(34) & (15) Participant #18 Jared Culbertson, RYAT – Mathematics, Computer Science

(3) Participant #3 Kirk Weigand, RYWA Workshop organizer (Broker)

(33) Participant #17 Mark Derriso, RHC-HF / Human Performance

(9) Participant #12 Steven Loscalzo, RISC, Computer Science

(57) & (2) Participant #2 Lori Westerkamp, RYA Systems Engineering

(70) & (4) Participant #5 Mike Talbert, RYA Systems Engineering

(25) Participant #8 John Raquet, AFIT/ENGE, Systems Engineering

(7) Participant #10 Mark Oxley, AFIT/ENC, Systems Engineering

(11) Participant #14 Kristen Kearns, RH - 711 HPW, Autonomy Initiative

(47) Participant #13 Aaron Linn, RYAR Systems Engineering

(76) Participant #16 Laurie Fenstermacher, RH 711 HPW, Anthropology, Human Factors

(43) Participant #6 Steve Rogers, RI, RY Systems Engineering

(68) Participant #22 Brian Abbe, RISC Information Science

2.2. Author-Nominated Stakeholders per Challenge

The following stakeholders were recommended by the participants in the Autonomy Steering Group SDD1. They are listed in order of proximity to the influence of Challenge 34 and include only the first level of proximity. The Challenge number is retained as indicating that if a specific person is not named then it is someone with expertise on the numbered challenge in the nominated organization.

2.1.1 Nominated Stakeholder Organizations and Specific Individuals

Stakeholder Organization Nominations for Challenges Similar to Challenge 34

(34) RYAR Raj Malhotra

(3) Sociology, Anthropology, CogSci, Math, Philosophy, Google, Users, Decision Makers

(33) RYA, RIS, RHC

(9 & 57) AFRL-Many!/Cross

(70) DCGS Modernizers, Next Gen UAS Avionics Developers

(9) an admonition to “learn about the domain to ensure effective spread”

(4 and 25 yet to recommend.)

Stakeholder Organization Nominations for Dependent Challenges of Challenge 34 (Challenge numbers are ordered by their position in the system of challenges left-to-right)

(7) AFIT, Mark Oxley

(15 and 4 are not yet nominated)

(70) DCGS Modernizers, Next Gen UAS Avionics Developers (also above)

(11) RQ, RI, RY, RW, CMV-SCI, ONR

(47) RI, RQ, DARPA CODE Program, DARPA SOSITE Program

(76) RHC Visualization, AFRL/DE New Symbol?, M&S Uncertainty People, BAE (CARS Work), Steve Banks

- *(43) ONRL*
- *(2) RYA, RYW, RYM ; and*
- *(68) UAV Operators*

2.3 Stakeholders in the Deep Driver (C34) & Similar Challenges

Challenge #34 Developing a Formalism for Situation Representation, Reasoning & Communication

This concerns developing the tools for a calculus of situations that can represent, manipulate, and change a situation internal to an agent such that it is dynamic. In order to communicate about the situation a Theory of Mind is required as part of your situational representation so that we also represent other agent's situational representation.

The Situation Representation Formalism should be Agnostic, Interdisciplinary, Flexible, Robust, Shared/Common, Unambiguous, Accurate, Compact and Intermediate to Diverse Data Sources and Modalities. (Authors of Challenges 3, 4, 9, 25, 33, 57, and 70.)

The nominated stakeholder organizations for each of these characteristics are:

Agnostic: AFRL-Many/Cross (9 & 57)

Interdisciplinary: Sociology, Anthropology, Cognitive Science, Math, Philosophy, Decision Makers (3)

Robust with respect to estimation: RYA, RIS, RHC (33)

Shared (Multiple) Common Representations: Learn about domain to ensure effective spread

Compact & Unambiguous: DCGS Modernizers, Next Generation Unmanned Aircraft System (UAS) Avionics Developers (70)

In addition to the authors of the above challenges there was an admonishment to learn about the domain in order to ensure “effective spread” (9).

The “customers”, or challenges dependent on progress in Challenge 34 ought to set forth requirements for addressing it. They are in order to proximity of influence the authors of each Challenge and the stakeholders’ representatives they recommend. AFIT, Mark Oxley (7); (15 and 4 not nominated); DCGS Modernizers, Next Gen UAS Avionics Developers (70); RQ, RI, RY, RW, CMV-SCI, ONR (11); RI, RQ, DARPA CODE Program, DARPA SOSITE Program (47); RHC Visualization, AFRL/DE New Symbol?, M&S Uncertainty People, BAE (CARS Work), Steve Banks (76); ORNL (43); RYA, RYW, RYM (2); and UAV Operators (68).

2.4 Author and Stakeholder Organizations by Challenge

Figure D-2 shows the SDD1 influence map marked up to show Author and Stakeholder Organizations by Challenge.

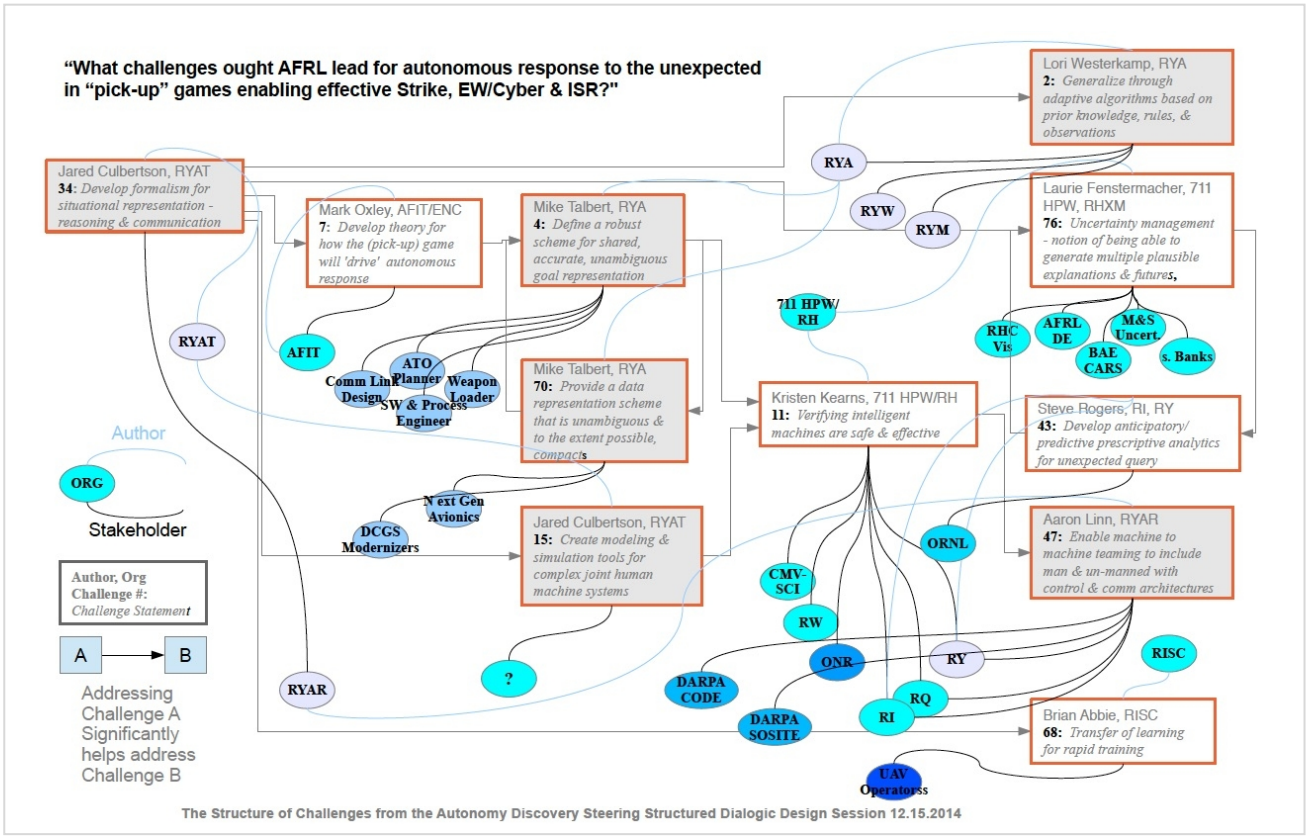

Figure C-2. SDD1 Influence Map by Author/Stakeholder per Challenge

The influence map is marked up to show the author, author organization and the stakeholders and customers of their organizations. (This diagram complements the previous mapping, as it omits all challenges similar to #34 and their authors and stakeholders.)

Appendix D. Index of Stakeholder Organizations

Internal / External Nominated Stakeholder Organizations

Divided by AFRL / non-AAFRL, Sorted by Organization Name, Challenge Number in Suffix

AFRL

AFIT, Mark Oxley (7)

AFRL-Many!/Cross (57)

AFRL-Many!/Cross (9)

AFRL/DE New Symbol? (76)

M&S Uncertainty People (76)

Steve Banks (76)

RHC (33)

RHC Visualization (76)

RI (11)

RI (47)

RIS (33)

RQ (11)

RQ (47)

RW (11)

RY (11)

RYA (2)

RYA (33)

RYAR Raj Malhotra (34)

RYM (2)

RYW (2)

External to AFRL

DCGS Modernizers (70)

BAE (CARS Work) (76)

CMV-SCI (11)

DARPA CODE Program (47)

DARPA SOSITE Program (47)

Google (3)

Next Gen UAS Avionics Developers (70)

ONR (11)

ORNL (43)
UAV Operators (68)
Users (3)
Decision Makers (3)
CogSci (3)
Math (3)
Philosophy (3)
Sociology (3)
Anthropology (3)
4 yet to recommend
15 yet to recommend
25 yet to recommend
Admonition to Learn about domain to ensure effective spread (9)

Authors Sorted by Organization

RH - 711 HPW (11) Participant #14 Kristen Kearns, Autonomy Initiative
RH 711 HPW (76) Participant #16 Laurie Fenstermacher, Anthropology, Human Factors
RHC - (33) Participant #17 Mark Derriso, Human Performance
RI, RY (43) Participant #6 Steve Rogers
RISC - (9) Participant #12 Steven Loscalzo, Computer Science
RISC - (68) Participant #22 Brian Abbe
RYA - (57) & (2) Participant #2 Lori Westerkamp
RYA - (70) & (4) Participant #5 Mike Talbert
RYAR - (47) Participant #13 Aaron Linn
RYAT - (34) & (15) Participant #18 Jared Culbertson - Mathematician
RYWA - (3) Participant #3 Kirk Weigand
AFIT/ENGE - (25) Participant #8 John Raquet, Systems Engineering
AFIT/ENC - (7) Participant #10 Mark Oxley, Systems Engineering

Appendix E. Preliminary Autonomy Taxonomy

C	Term from Challenges	Prelim definition	References & Qualifiers
	Definitions		
1	Autonomous	Operating fully independently of human control.	What is necessary "to go from autonomy to autonomous."
1	Autonomy	Doctrine of ISR and warfighting enabled by autonomous vehicles & systems.	As a process and technology architecture
1	Autonomous systems	Independent, intelligent operational actors and networks functioning within command structure	Flexible, Resilient
2	Adaptive algorithms	Computer programs for core ops functions that learn and change capabilities based on situation and environmental requirements	Algorithm that changes its behavior based on information available at the time it is run
	Formalisms		
3	Situation representation (vis Situational)	Situation representation is defined as an encoded formalism that describes a situation of interest sufficiently for taking ISR, EW or CID actions.	Situation calculus (1991) McCarthy & Reiter: A situation represents a history of action occurrences, not a state.
3	Representational formalism for situations.	Challenge as stated:	Interdisciplinary,
4	Unambiguous goal representation.	There is significant ambiguity with respect to the challenge: Are the system goals or the actors' goals to be unambiguously indicated?	What goals? Why must they be unambiguous if in reality goals are over-attributed and misleading?
	Operations		

C	Term from Challenges	Prelim definition	References & Qualifiers
	Situation awareness	The ability to maintain a constant, clear mental picture of relevant information and the tactical situation including friendly and threat situations.	
5	Phase 3 insight	Relevant to full-spectrum awareness in ISR 2023, Phase 3 (Dominate)	Phases 1,2,3
6	Autonomous coalition forming		Diverse vehicles
	Formalisms		
7	Theory for: How the game will drive the autonomous response.		
8	Real-time situational awareness models		Blasch, et al (2006). Issues and Challenges in Situation Assessment (Level 2 Fusion)
9	Rapid inference.		
10	Mission, architecture, environment and situational awareness.		
11	Verification (of machines)		Safe and effective.
12	Adaptable software, firmware, hardware for threat detection	Need for cyber systems to adapt to "Zero Day Threats" with no precedent, to detect & respond to never before seen threats.	
13	Embed ethics/morals	"Algorithms will have to make some decisions and so what are we going to base those decisions on when they do that when they could very well apply lethal force or they could be doing something that has significant political ramifications. So how are we going to bound their behaviors?" SDD1	
14	Decision making.		

C	Term from Challenges	Prelim definition	References & Qualifiers
15	Modeling simulation tools for complex joint human machine systems.		
17	Denied targets, denied territory		
18	Geographically dormant areas.	Overlooked but geopolitically significant regions that remain below active thresholds	
18	Tipping, cueing, triage	An active recon approach that scans social sources for semantic cues & references from across sources (rel to ISR Soak?)	Social Media
19	C2 architecture		
19	Multiagent systems. (Swarms cyber)		
21	Levels of distribution.		
21	Resource management		
22	Social radar		
22	Patterns of life and intentions.		
23	Mission decomposition schemes		partitioning of available resources.
24	Find relevant sources multidomain to impact decisions for pick up issues.		BRO-network
25	Information representation scheme		
27	Human machine sliding decision methodology		Decision making
28	Learning methods		"Harden to thrive despite corrupt/malicious inputs".
21	Resource management for platforms …		information architectures, sensors, air crews and analysts

C	Term from Challenges	Prelim definition	References & Qualifiers
30	Represent and understand priorities		
30	information rep -humans and machines individually and together.		
31	Real-time threat assessment and understanding to develop defensive cyber protections.		
32	Unambiguous		natural language communication.
33	Robust status information and representation for enhanced decision making		information and representation for enhanced decision making.
34	(34) Formalisms for situational representations		Reasoning and communication.
35	Task decomposition, planning and replanning.		
36	Anticipatory algorithms for responsive adaptive F2T2EA.		
37	ISR "soak."		Expendable, meaning?
38	Autonomous planning systems.		Develop resilient/dynamic
40	Modeling and simulation on closed-loop systems		to support closed loop experimentation.
41	Hybrid organizational forms - partnering		
42	Comms between agents in a network community.		insure trusted possibly ad hoc
43	Anticipatory/predictive/		Unexpected query

C	Term from Challenges	Prelim definition	References & Qualifiers
	prescriptive analytics		
45	Human state sensing and assessment		
46	Trustworthiness metrics and methodologies		
46	Reliable and verifiable (machine) learning		
47	Enable manned and unmanned machine to machine teaming		with control and Comm architectures.
48	Machines that understand the environment & threats.		
49	Software and hardware tools for sensing malicious behavior		
50	Understand "gut feel decision making"		
	QuEST		
51	Develop infrastructure for sensing as a service.	Rogers: "Sensors as information services connected by robust battlespace networks transforms the sensing paradigm to serve the needs of many independent users."	
52	Machine understanding of mission context, objectives and intent.		
53	Adaptive networks for multiple UAS in denied comm environment.		
54	Nontraditional multi-INT.		
55	Cooperative engagement of multiagent systems.		
56	Methods to detect deliberate deception.		
57	Represent decisions and data in a compact		

C	Term from Challenges	Prelim definition	References & Qualifiers
	and agnostic form.		
58	Autonomy skunk works (hybrid org)		
59	Industry standards		to allow the ad hoc nature of solutions.
60	Agile/flexible ISR/CID/EW system of systems.		
61	Understand and predict human intent via remote sensing.		
62	Transfer learning.		Speed decision making times
63	Feedback between analysts/air crews & sensing resources.		
64	Resilient systems to mitigate undetected threats.		
65	Real world scale reasoning and learning.		
66	Framework for sharing decisions at metalevels.		
67	Single source ISR/ATO tasking.		
68	Transfer learning for rapid training.		
69	Manage uncertainty from origin to decision to human ingestion.		
70	Data representation scheme		Unambiguous and to the extent possible, compact.
71	HCI - Present ISR and EW info effectively to air crews/analysts.		
72	Neurologically inspired machine learning and prediction algorithms		Rapid threat recognition and response.

C	Term from Challenges	Prelim definition	References & Qualifiers
73	Model performance to support decision algorithms.		
74	Situated IPOE	Situated intelligence preparation in the operational environment. Enable analysts & planners to reason about what they know/don't know	Relevant to unexpected query. Cognitive IPOE, types of knowledge. (Also physiological, behavioral and emotional)
75	Bootstrap analyst/ planner contextualized understanding of the human environment		
76	Uncertainty management		
77	Represent and understand priority information (human and machines) individually and together.		
78	Interoperability		
80	Represent and understand priority information (human and machines) individually and together.		

Appendix F. Structured Dialogic Design – Challenges Analysis

1. SDD Workshop Overview

The SDD1 workshop (15 December 2014) was planned to be entirely accomplished within a single business day, which even in the best circumstances is a difficult achievement, entailing known but acceptable risks to outcome. A typical SDD workshop exploring a complex question with a comparatively large group of over 20 participants would require 12 hours or more of engagement, due the necessary time to conduct software-based voting on between 15-20 challenges. The SDD1 workshop produced 90 total responses to the triggering question, 75 of which were determined to be distinct and non-overlapping. A total of 16 challenges received 2 votes or more (selected for inclusion in software voting).

The attempt to accomplish structuring most of these selected 2+ vote challenges was successful, but it involved trade-offs. We used creative, rapid methods for clustering over the lunch period. We were unable to continue structuring or to amend the influence map within the course of the workshop, given the hard start and stop times dictated by the Tec^EDGE facility.

An additional 16 challenges received 1 vote. Given the key principle recognized in SDD (the *erroneous priorities effect*) there is a high probability that a “deeper driver” in the challenge network might have been discovered in the challenges with only one or two votes. Therefore, while we are confident that the workshop group performed extremely well in a single day given the workshop process (effectiveness was high), our confidence in completeness is somewhat lower. However, the first SDD workshop with a steering group can be considered a scoping session of sorts, a means of gathering as many well-considered challenges as possible and selecting and mapping them to the research contexts of interest.

2. Analysis and Findings

The focus on “pick-up games” was included to establish a compelling purposeful need for proposed challenges that might address the particular hard cases of uncertainty represented by emergent and unforeseen threat situations.

2.1 High Leverage Challenges

The influence diagram generated from the collaborative foresight workshop denotes a set of related challenges in a network that reflects the majority voting of the relations between challenges. We can establish that Challenge 34 was the deepest driver (at Level 5) and had the farthest reach across challenges:

34: Develop formalism for situation representation - reasoning & communication

While directly linked to all other challenges in the network, 34 was most closely linked (Level 4) to 7:

7: Develop theory for how the (pick-up) game will ‘drive’ autonomous response

Challenge 7 connected the cycle of two challenges at Level 3, which were nearly identical propositions:

4: Define a robust scheme for shared, accurate, unambiguous goal representation

70: Provide a data representation scheme that is unambiguous & to the extent possible, compact

These connect Challenge 15 (modeling & simulation tools for complex joint human machine systems) to Challenge **11:** *Verifying intelligent machines are safe & effective*

This “inner ring” of related issues terminates in Challenge 47 at the top level:

47: Enable machine to machine teaming to include man & un-manned with control & comm architectures

At Level 1, challenge 47 can also be seen as a desired outcome and goal of the related projects and the triggering question itself.

Deep drivers (34 and 7) have the most influence on other challenges and have the highest reachability score. They were judged to enable the most leverage for accomplishing progress on the immediate linked challenges and the totality of the challenges in the system.

Of course, other challenges not included might be found later to have significant leverage as well, and may have been excluded due to the time allotment for structuring (voting) or having fewer than 2 preference votes (initial dot voting). If such an exclusion error exists, it is similar to accepting a false positive that 34 and 7 were the deepest level challenges. With 76 challenges it is impossible to include them all, but the chances of excluding or overlooking significant challenges is minimized by clarification for group understanding, and amending rounds of voting and clustering.

A working composite of attributes for the clarification of the merged Challenge 34 is proposed.

Developing a Formalism for Situation Representation, Reasoning & Communication. It should be Agnostic, Interdisciplinary, Flexible, Robust, Shared/Common, Unambiguous, Accurate, Compact and Intermediate to Diverse Data Sources and Modalities.

2.2 Analysis of Categories / Topics

Challenges were clustered and associated with the 13 themes from the 15 September 2014 Discovery workshop. The set of 76 challenges associated with these themes represent the full range of challenges included in the structuring (duplicate and discarded challenges are not included). Those challenges receiving two or more votes (candidates for structuring) are shown in bold blue.

Cluster 1: Stovepipes, Cultural Impediments

37: Expendable ISR 'Soak' (2)

41: Increase Funding/Partnering By 100db

58: Create an Autonomy 'Skunk Works'

60: Develop Agile/Flexible ISR/CID/EW CYBER SOS

67: Develop Single Source ISR ATO Tasking

Cluster 5: Artificial Consciousness (QuEST)

5: Enabling Phase 3 Insights in Phase 1 Timelines

34: Developing Formalism for Situational Representation – Reasoning and Communication (4)

43: Develop Anticipatory/Predictive Prescriptive Analytics for Unexpected Query (4)

Cluster 6: Social Radar for Meaning Making

18: Tipping, Cueing Triage – Social Media in Geographically Dormant Areas (2)

22: Generate Narratives for Social Radar, Patterns of Life and Intentions

75: Boot Strap Analyst/ Planner Contextualized Understanding of the Human Environment

Cluster 7: Mistrust in Human-Computer Interaction

14: Improve Interface Interaction between Human and Machine for Rapid Effective Decision Making (2)

15: Create Modeling Simulation Tools for Complex Joint Human-Machine Systems (4)

30: Represent and Understand Priority Information – Human and Machines Individually and Together

46: Establish Trust-Worthiness Metrics and Methodologies for Reliable and Verifiable Learning

47: Enable Machine-to-Machine Teaming to Include Man and Unmanned With Control and Comm Architectures (5)

Cluster 8: Taxonomies

44: Agree on the Meaning of these Terms (2)

57: Represent Decisions and Data in a Compact and Agnostic Form

Cluster 9: Black Swan Surprise

28: Harden Learning Methods to Thrive Despite Corrupt/Malicious Inputs

74: Situated IPOE: Enable Analysts to Reason about What They Know/Don't Know

76: Uncertainty Management – Being Able to Generate Multiple Plausible Explanations & Futures (4)

Cluster 10: Automated Intent

31: Perform Real-Time Threat Assessment and Understanding to Develop Defensive Cyber Protections

36: Create Anticipatory Algorithms for Responsive, Adaptive F2T2EA (2)

49: Develop Software and Hardware Tools for Sensing Malicious Behavior

61: Understand and Predict Human Intent via Remote Sensing

Cluster 11: Quantify & Characterize

15: Create Modeling and Simulation Tools for Complex Joint Human-Machine Systems

17: Flexible and Adaptive Sensing for Denied Targets

25: Develop Flexible Information Representation Scheme, Associated Interface Standards

29: Create Resource Management for Platforms, Info. Architectures, Sensors, Air Crews and Analysts

40: Modeling and Simulation to Support Closed Loop Experimentation

55: Develop Autonomous Cooperative Engagement of Multiagent Systems

63: Provide a Feedback Capability between Analyst/Air Crews and Sensing Resources

73: Model Performance to Support Decision Algorithms

Cluster 12: Substrate of Autonomy

3: Build an Interdisciplinary Representational Formalism for Situations

9: Represent Diverse Data Sources to Facilitate Rapid Inference

10: Develop Flexible Autonomy based on Mission Architecture, Environment, Situational Awareness

12: Build Adaptable Software, Firmware, Hardware to Detect Never Before Seen Threats

13: Embed Ethics/Morals

16: Resilient Autonomous Systems

19: Develop C2 Architecture of Multiagent Systems (Swarms Cyber)

32: Unambiguous Natural Communication

33: Improve Robustness in State Estimations, Representation for Enhanced Decision Making

34: Developing Formalism for Situational Representation – Reasoning and Communication

42: Ensure Trusted, Possibly Ad Hoc Comms between Agents in a Networked Community

48: Enable Machines that Understand the Environments and Threats

57: Represent Decisions and Data in a Compact and Agnostic Form

59: Define Industry Standards to Allow the Ad Hoc Nature of Solutions

65: Real World Scale Reasoning and Learning (2)

66: Create Framework for Sharing Decisions at Meta-Levels

70: Provide a Data Representation Scheme that is Unambiguous and to the Extent Possible, Compact (2)

Cluster 13: Outliers

11: Verifying Intelligent Machines Are Safe and Effective

46: Establish Trust-Worthiness Metrics and Methodologies for Reliable and Verifiable Learning

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Glossary

Categories *- In the SDD process defined in this report, categories are the labels of clusters which conclude the clustering phase of the methodology.*

Clustering - This is a collection of methods, based on induction and pattern recognition, which are employed to enable participants to envision the overall gestalt of a set of statements. It is based on identifying the similarity or 'family resemblance' of statements and constructing categories which label family membership. Clustering was employed during each workshop - once for challenges and once for solutions. One of the clustering methods employed in this workshop is called the KJ Method for creating Affinity Diagrams developed by Kawakita Jiro.

Collaborative Foresight – A model of Structured Dialogic Design oriented toward collaborative futures, where long-term systemic problems are engaged through strategic foresight by engaging multiple stakeholders in collaborative problem identification and strategic resolution.

Collaborative Planning - A style of planning design and deliberation in which participants generate the content in a bottom-up methodology for a given planning context. The definitive source for this model is based on McKearney, T. J. (2000), Collaborative Planning for Military Operations: Emerging Technologies and Changing Command Organizations. In this approach organizational leaders guide the composition of a driving question and engage participants in a collaborative, bottom-up planning approach.

Common Technical Trajectory – A strategic planning model of related science and technology projects and activities associated with a common strategy over a given timeframe used in R&D planning and management.

Consensus - Several mechanisms are employed for encouraging unanimity in the SDD process. First, during the voting on the importance of challenges (or solutions), any challenge that at least two people agreed to carry forward were honored. Secondly, during clustering all participants were asked to make adjustments to the groupings. Thirdly, application of the Interpretive Structural Modeling method employed "supermajority," two-thirds votes which over the course of the session moved towards many unanimous votes regarding influence.

Cross-Impact Analysis - This refers to several steps in the process including Cross-Impact Mapping, identification of goals, touchpoints, and evaluation of the overall influence of solutions on the total system of solutions and challenges.

Cross-Impact Mapping - This method connects the system of solutions to the system of challenges. In this application the connections were derived in two steps. First, participants were asked to identify solutions that would influence the resolution of deeply influential challenges in the system of challenges. The authors of the solutions nominated the influence on challenges on their proposed solutions. In the second step additional influences of solutions upon challenges was evaluated by a participant with subsequent review of the proposed mapping.

Consensus Influence Structure - The result of the Interpretative Structural Modeling method which is based on supermajority, 2/3 majority voting, and leads to

a series of near unanimous votes on the influence of one challenge upon another (or one solution upon another.)

Cycles - The mutual influence of one challenge on another, or one solution upon another. These are typically represented as multiple statements within the same box (so-called box-and-pointer notation.)

Deep Drivers - The most influential solutions in the system of solutions. This may also refer the most influential challenges in the system of challenges. The latter is also referred to as "root causes." Deep Drivers are considered to be "highly leveraging" or "highly influential" regarding progress on other solutions and the resolution of challenges.

Directed Acyclic Graph - The structure which results from Interpretive Structural Modeling is a graph composed of nodes and arrows. Statements, such as challenges, are the nodes. The influences are 'directed' and represented by an arrow with one head, form one node to another. The diagram of the influence of one challenge upon another is 'acyclic' in that the diagram does not represent nodes influencing themselves.

Erroneous Priorities - This is a phenomena observed regarding a discrepancy of challenges which receive high votes of importance, which turn out not to be very influential in the overall system of challenges. (Or similarly for solutions.)

Goals - Some challenges, identified by the participants, after review by senior leadership on the group, were acknowledged as overall long-range goals.

Influence Map - The structure, of 'system of challenges' (or system of solutions" which results from the application of Interpretive Structural Modeling. It is a particular kind of structured referred to as a Directed Acyclic Graph.

Influential - also see Strongly Influential - If a particular challenge is judged to influence a large portion of the overall system of challenges it is considered 'influential." More formally, a challenge considered 'influential' would exhibit a high 'reachability' score - which is the sum its row in the reachability matrix. This is of course similarly true of solutions, as well as the overall cross-impact system of solutions and challenges. Items considered 'influential' are also said to have 'leverage.'

Initial Preferences - In the SDD process, individual voting on the importance of a challenge (or solution) is employed primarily as a 'preference' for focusing further inquiry in the group. After the clustering step the criteria for aggregate preference for the group was to select all statements which at least two people expressed a preference for further inquiry.

Interpretive Structural Modeling – A matrix algebra method developed by John Warfield, based on the forced juxtaposition of statements, to assess systemic relationships, such as the transitive relations in terms of influence. ISM was employed in developing the system of challenges represented in an influence map.

Leverage - refers to solutions which have a comparatively high degree of influence on other solutions and challenges. It is also said that progress on a deep driving challenge would 'leverage' progress on another.

Pick-up Game – Also known a “zero day event” the label refers to a emergent situation arising within a geographical context of initially unknown political or military impact, wherein multiple parties may have an interest and coordination between participants becomes essential.

Preference Votes - These are the assignment of importance to statements which will be carried into the subsequent application of additional inquiry methods.

Reachability - This is the sum of influences one challenge has on other challenges in the system of challenges. This is also a measure of the influence of solutions on other solutions as well as on the system of challenges - in the superposition structure (i.e. cross-impact map).

Stakeholder Participants - The set of participants are selected to represent the diversity of viewpoints in the stakeholders of the organization. In this sense they are similar to a senate.

Strategy Pathways - Outlines the system of challenges as a set of influence relationships among challenges and how a set of solutions map to the system of challenges.

Strongly influential - Those challenges which have a comparatively large influence on other challenges are said to be "strongly influential." More formally, it is those challenges which appear in the lower half of the reachability matrix. The cumulative row summations in the reachability matrix exhibit the classic Pareto, 80/20 law - that is it is those 20% of the challenges which collectively exhibit 80% of the total influence on the system of challenges. This is similarly the case for solutions' influence on the system of solutions as well as on the cross-impact mapping of the system of solutions upon the system of challenges.

Structured Dialogic Design (SDD) - A registered service mark of the Institute for Agoras of the 21st Century for the multistakeholder dialogue engagement method for collaborative challenge resolution. SDD is evolution of the practice of Interactive Management developed by John Warfield and Alexander Christakis, and is mediated by one of several software systems, including the CogniSystem and logosofia.

SDD1 – The 15 Dec 2014 Autonomy workshop sponsored by AFRL/RYW and RYA

SDD2 – Second in series of AFRL SDD workshops planned for the Autonomy Discovery collaboration.

SDD3 – A third in series of AFRL SDD workshops planned for the Autonomy Discovery collaboration.

Structuring – Vernacular reference to the process of employing Interpretive Structural Modeling in an SSD workshop.

Superposition - See Cross-Impact Mapping

Systemic relationships - In this application this is the collection of influences among the set of solutions and the set of challenges.

System of solutions and challenges - The results of Interpretive Structural Modeling of the solutions and that of the challenges as well as their superposition, or cross-impact mapping of the them both.

Themes - This term is employed in several ways in the report: as a correspondence between challenge and solution categories; it refers to the attributes of Cognitive Autonomic Response, Trusted Systems, and Fractionated Effects, the so-called "Three Bubbles"; it is used to refer to the challenge and solution categories which result from clustering; it also refers to "core planning themes" developed in parallel by the Technical Advisors.

Touchpoints - Are those challenges in which responsibility is shared with another organization, thus requiring coordination.

Triggering Question - This is the focus of inquiry for the workshop. There were two Triggering Questions in this engagement, one intended to elicit technical challenges over the next twenty years and one to elicit Science and Technology solution options to address the system of challenges.

List of Symbols, Acronyms, and Abbreviations

A2AD	Anti-Access/Area Denial
ATO	Air Tasking Order
C2	Command and Control
CID	Combat Identification
CONOPS	Concept of Operations
Cyber	Cybersecurity (defense intervention)
DOTMLPF-P	Doctrine, Organization, Training, Materiel, Leadership and Education, Personnel, Facilities and Policy
DDI	Dialogic Design International
DCGS	Distributed Common Ground System
EW	Electronic Warfare
F2T2EA	Find, Fix, Track, Target, Engage, Assess.
HF	Human Factors
ISM	Interpretive Structural Modeling
ISR	Intelligence, Surveillance and Reconnaissance
OSD	Office of the Secretary of Defense
OSDA	Open Service Discovery Architecture
QuEST	QUalia Exploitation of Sensing Technology
R&D	Research and Development
SDD	Structured Dialogic Design[SM]