AIRC | ACQUISITION INNOVATION RESEARCH CENTER

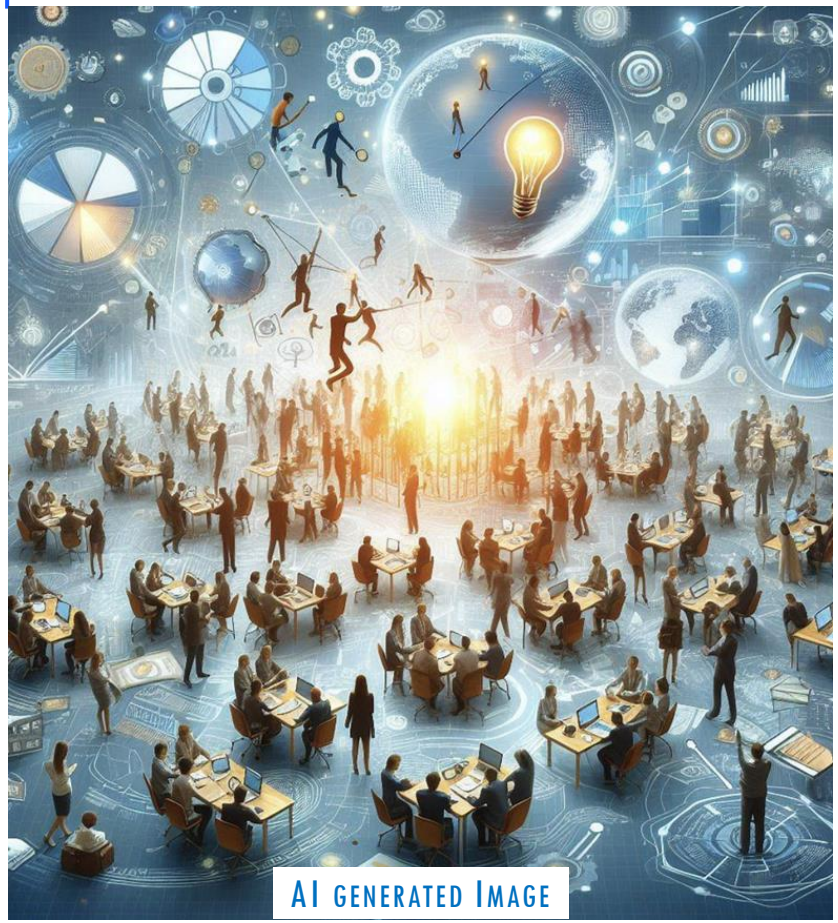
Quarterly Research Forum

The Future of Managing Megaprojects

(AIRC project WRT-1082)

June 14, 2024

Agenda



12:00 p.m. ET: Project introduction and status

12:15 p.m. ET: A framework to analyze megaproject uncertainty

12:30 p.m. ET: Summary of Lessons Learned by category

1:30 p.m. ET: Adjourn

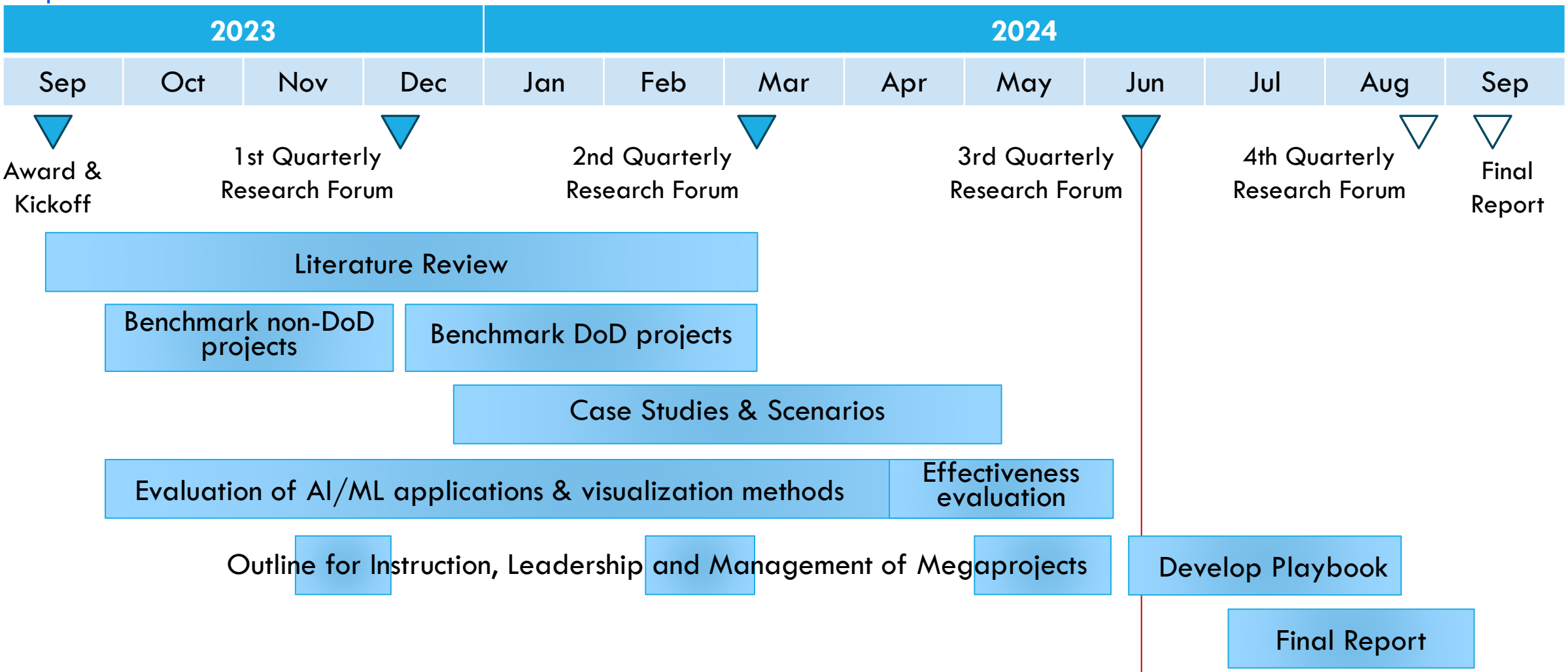
Project Approach

Conduct a literature review across the areas of megaproject management, leadership, project data collection, visualization, visualization effects on human decision making, and emerging AI/ML project management trends.

Look at both non-DoD and DoD megaprojects. What are the megatrends, trends, and bellwethers that will shape how DAU should train and educate the Defense Acquisition Workforce in 10 to 15 years?

Explore how the use of data visualization, AI, and machine learning (ML) can be combined with leadership practices to aid in the management of DoD megaprojects. Deliver a series of web events to the Acquisition Workforce focused on the practical use of visualization, AI, and ML to improve program management.

Project Plan



What is a Megaproject?

- "large-scale, complex ventures that typically cost $1 billion or more, take many years to develop and build, involve multiple public and private stakeholders, are transformational, and impact millions of people."
  - Oxford Handbook of Megaproject Management (Flyvbjerg, ed., 2017)
- "often produce mega-systems that operate with dimensions of behavioral complexity, pluralistic multi-actor decision-making, high criticality, and volatility of the external environment."
  - Engineering Mega-Systems (Stevens 2017)
- "often combine uncertainty with the difficulties of long time horizons and nonstandard technologies."
  - S. Lenfle and C. Loch, "Has Megaproject Management Lost its Way: Lessons from History." in The Oxford Handbook of Megaproject Management

The DoD has long-been a sponsor of megaprojects, and also continues to transition from more standalone platform centric systems to mega-systems.

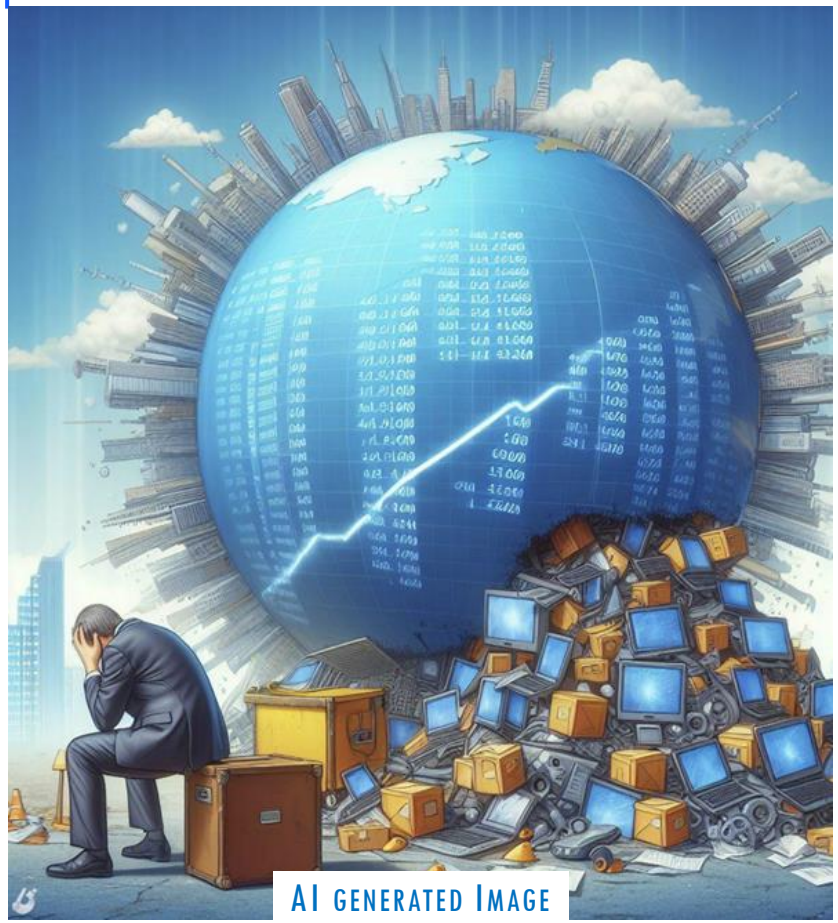
Derived Common Analytical Characteristics of Megaprojects

- Large scale, complex interfaces
- Behavioral and structural complexity, high levels of uncertainty
- Often non-standard technology and design
- Transformational outcomes
- Long planning horizons, scope changes significantly over time
- Pluralistic, multi-stakeholder influence and decision-making
- Specialized enterprise leadership skills
- Complex external environment and over-commitment

1. Uncertain outcomes: "Fat Tails"
2. Experience major lifecycle shifts
3. Complexity drives uncertainty and management of uncertainty
4. Success/failure difficult to predict, lack of causality
5. Transformational leadership abilities required

The Oxford Handbook of Megaproject Management (Oxford Handbooks) (p. 8). OUP Oxford.

Agenda



AI generated Image

12:00 p.m. ET: Project introduction and status

12:15 p.m. ET: A framework to analyze megaproject uncertainty

12:30 p.m. ET: Summary of Lessons Learned by category

1:30 p.m. ET: Adjourn

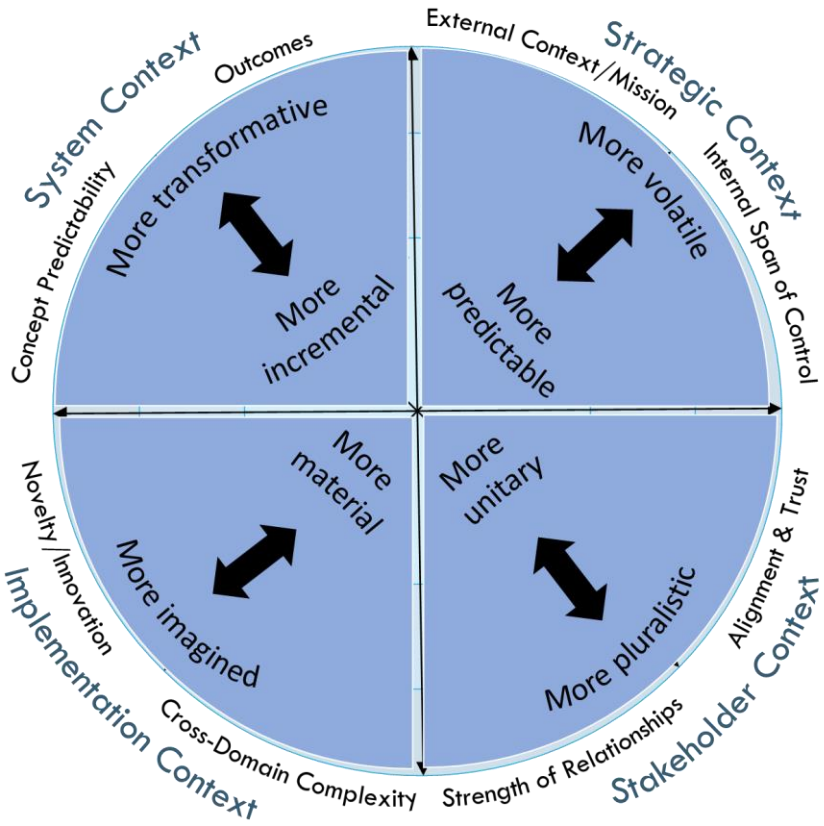
COMPLEXITY DRIVES UNCERTAINTY AND MANAGEMENT OF UNCERTAINTY

- While projects focus on progress to plans, megaprojects should focus on discovery of and burndown of uncertainties.
- Based on extensive literature review, we created a Megaproject Uncertainty Framework as a decision aid in characterizing megaproject uncertainty dimensions and identifying strategies to combat "fat tails." This framework has four uses:

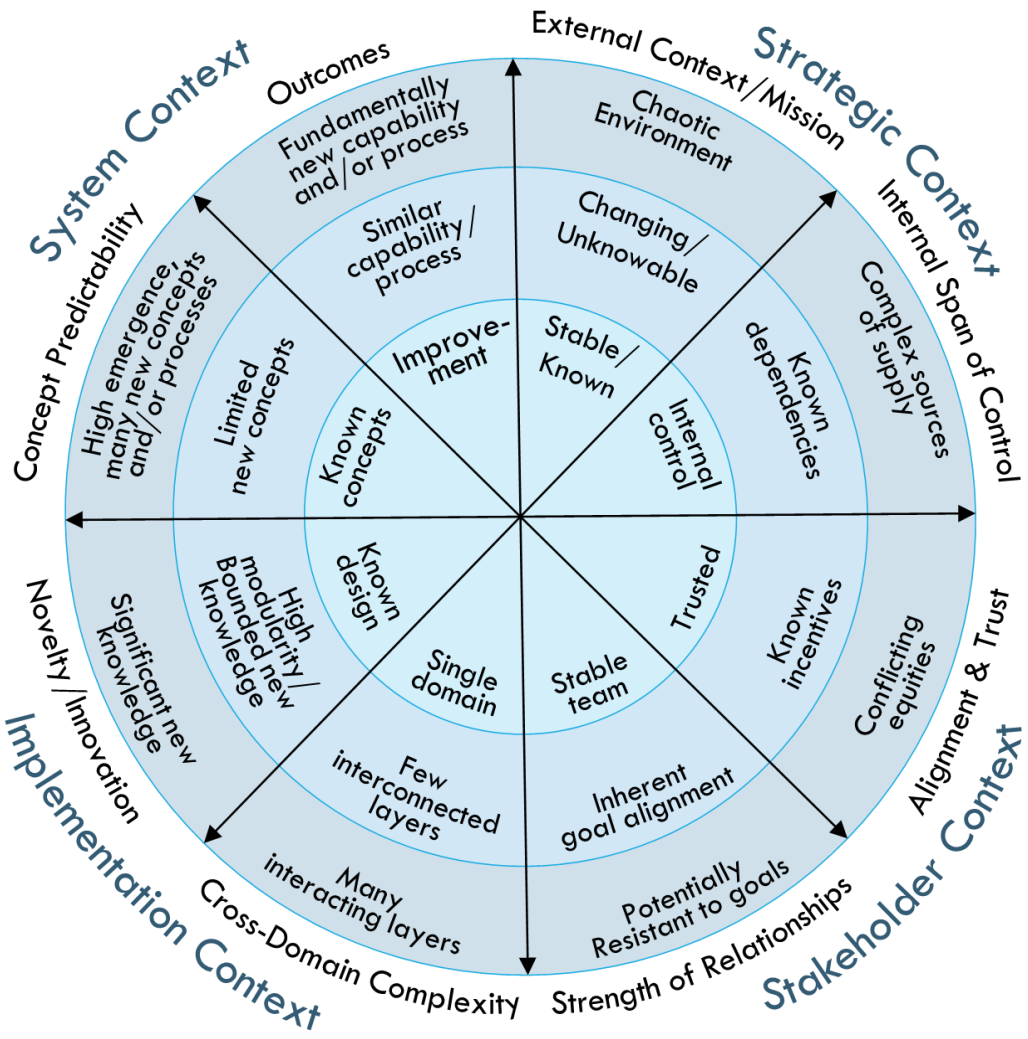
1. It is a qualitative rubric used to organize learning from case studies.
2. It is an assessment framework that can be used to model and actively track megaproject uncertainties over time to design/redesign the project.
3. It will create an analytical framework (visualization dashboard) for guiding data visualization and analysis in megaproject execution.
4. It will inform a leadership and management model to train the future class of megaproject and mega-system leaders.

COMPLEXITY DRIVES UNCERTAINTY AND MANAGEMENT OF UNCERTAINTY

4 Contexts



8 Strategies



Adapted from Stevens, R. (2011). Engineering Mega-Systems: The Challenge of Systems Engineering in the Information Age.
Schindler, S. (2019). Contemporary Megaprojects: Organization, Vision, and Resistance in the 21st Century.

Megaproject Characteristics and Management Strategies (1)

Megaproject Characteristics	Potential Management Strategies
1) inherently risky because of long planning horizons and complex interfaces	practice risk management but also rigorously evaluate project uncertainties that may lead to risks in later stages
2) often led by planners and managers without deep domain experience, who keep changing throughout the long project cycles	select leadership with skills for megaproject leadership, and carefully manage leadership changes over time
3) multi-actor pluralistic decision making, planning, and management involving multiple stakeholders with conflicting interests	build integrated teams and leadership strategies that create alignment to larger project goals and instill trust
4) often non-standard technology and design, leading to uniqueness bias among planners and managers	limit technical risk, and mature critical technologies outside of project schedule and cost
5) overcommitment at the early project stages, leading to lock-in, poor alternatives analysis, and escalated commitment in later stages	involve critical external and internal stakeholders in incremental decision processes

Bent Flyvbjerg, 2017, "Introduction: The Iron Law of Megaproject Management," in Bent Flyvbjerg, ed., The Oxford Handbook of Megaproject Management (Oxford: Oxford University Press), Chapter 1, pp. 1-18

Derived from project literature reviews and interviews

Megaproject Characteristics and Management Strategies (2)

Megaproject Characteristics	Potential Management Strategies
6) involve large sums of money, leading to principal-agent problems, rent-seeking behaviors, and optimism bias	structure contracts to emphasize management of uncertainty and problem-solving instead of assumed successful outcomes
7) project scope and ambitions typically change significantly over time	employ incremental decision making at the "last responsible moment"
8) project delivery is a high-risk stochastic activity with overexposure to extreme events with massively negative outcomes	"execute fast" – reduce exposure by accelerating schedule when burn rates are high; exercise scenarios for extreme events and build resilience strategies for project execution
9) complexity and unplanned events are often unaccounted for, leading to inadequate budget and time contingencies	build centralized risk pools and monetary incentives for problem solving
10) misinformation about costs, schedules, benefits and risks is the norm throughout project development and decision making	employ emerging technologies for data analysis and visualization that can monitor and alert for emerging project risks

Bent Flyvbjerg, 2017, "Introduction: The Iron Law of Megaproject Management," in Bent Flyvbjerg, ed., The Oxford Handbook of Megaproject Management (Oxford: Oxford University Press), Chapter 1, pp. 1-18

Derived from project literature reviews and interviews

Mega-System Characteristics and Management Strategies

Mega-system Characteristics	Potential Management Strategies
11) decentralized execution and leadership creates diffusion of leadership and authorities	develop strategies for multi-organizational alignment to larger project goals, often set by central authorities (governments)
12) envisioned large-scale system transformations defy traditional development and management processes	develop transformative decision making processes to execute the projects in addition to the system transformation
13) concept of equifinality: there are multiple routes to a specific set of outcomes	conduct multiple planning cases, invest in parallel development of alternatives
14) difficult to predict which concepts will survive to the mega-system completion	invest in experimentation to build knowledge and reduce uncertainties
15) difficult to predict the interactions between different systems and related disciplines, leading to non-holistic decisions	model the adjunct relationships between different systems and decisions

Derived from project literature reviews and interviews

Derived from project literature reviews and interviews

1. Uncertain outcomes: "Fat Tails"
2. Experience major lifecycle shifts

"Think slow ….. Execute fast" "The Hiding Hand"

Project Planning Phase	Project Execution Phase	Project Benefits Phase

- "Think slow" – it's a serious mistake to treat planning as an exercise in abstract bureaucratic thought and calculation. What sets good planning apart from the rest is something completely different. It is experimentation and experience (learning).
- "Execute fast" – time kills megaprojects, not size. Act fast to reduce changing externalities.
- "The Hiding Hand" – imagined transformative benefits often drive megaproject business cases. Ignorance can provoke creative success (Hirshman), but only given a benevolent hand (Flyvbjerg).
- Equifinality (complexity theory) – in a complex system there are multiple routes to a specific set of outcomes; more complexity needs more diversity in planning cases. Predicting areas of uncertainty is critical to planning.

Issues with Uncertainty

- The management of risks fundamentally differs from the management of uncertainty, projects have both
- Classic project management has a long tradition of managing project risks (it is mature)
- The concept of uncertainty has neither been clearly addressed by classic project management, nor is it explicitly defined in widely accepted project management standards
- "Risk and uncertainty are not differentiated and are being used synonymously—or, more precisely, uncertainty is treated as a special case of risk

Thomas G. Lechler, Ting Gao, Barbara Edington, The Silver Lining of Project Uncertainties, Project Management Institute 2013

Classifications of Uncertainty

Table 3.1: Classifications of Uncertainty https://analystsuncertaintytoolkit.github.io/UncertaintyWeb/chapter_3.html

Classification	Aleatory uncertainty	Known unknowns - Epistemic uncertainty	Unknown unknowns - Ontological, Structural and Deep uncertainty*
Definition	Sometimes referred to as "known knowns", aleatory uncertainty is the **things we know that we know**. This refers to the inherent uncertainty that is always present due to underlying probabilistic variability.	Known unknowns are **things that we know we don't know**. This type of uncertainty comes from a lack of knowledge about the (complex) system we are trying to model. Assumptions are used to plug these gaps in the absence of information.	Unknown unknowns are **things that we don't know we don't know** . It usually comes from factors or situations that we have not previously experienced and therefore, while we can still think about it, we cannot consider it to the same level of detail as other forms of uncertainty.
Can it be quantified?	**Yes** it can be quantified. We usually characterise it using a probability distribution function (PDF). A PDF gives all the possible values that a variable can have and assigns a probability of occurrence to each. As analysts, the challenge for us is to derive the PDF. If you find that you can't then you may instead have a known unknown.	**Yes** it can be quantified (but isn't always) – e.g. through sensitivity analysis. These techniques try to quantify the uncertainty by altering assumptions and observing the impact on modelling outputs. They will work if the range of assumptions tested covers the range of unknown variables.	**No**, although it's likely effect upon our analysis can be qualitatively assessed (see the Evidence Framework Approach outlined in **Glover and Pearce (2020)**) through reference to similar things that we do know more about. What we must do is be clear about the sources of uncertainty we have recognised, enabling other sources subsequently identified to likely add to that uncertainty.
Can it be reduced?	This type of uncertainty cannot be completely removed. We can sometimes reduce it through data smoothing or increasing the size of a sample, but there will always be some random variability.	Known unknowns are reducible by gathering information to lessen the gaps in our knowledge. Using new data sources, expanding our data collection or conducting research can remove the need for assumptions or refine their ranges.	This type of uncertainty can usually be reduced through further work, although this may take some time. It can also usefully be separated into "unknowable unknowns" and "knowable unknowns". Once they are identified they become known unknowns.

Assumptions Mapping

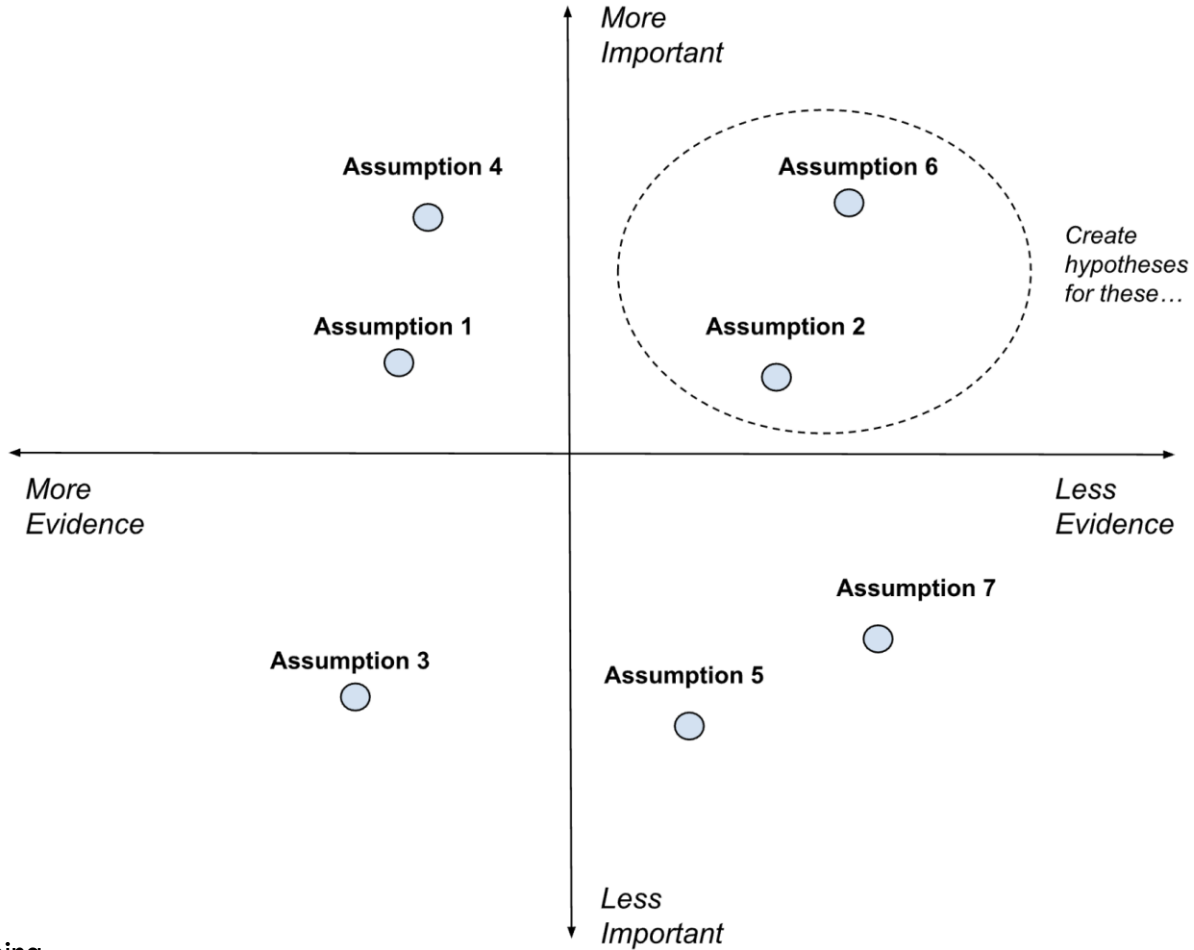
Make implicit assumptions explicit. The leadership team must document them to drive a shared understanding. ➔

Explore ways to "buy information" via research, experiments, or incremental development.

Create hypotheses statements for the proposed actions for each assumption in the quadrant.

Set near-term outcomes for each assumption.

Track evidence that turns assumptions into knowledge.

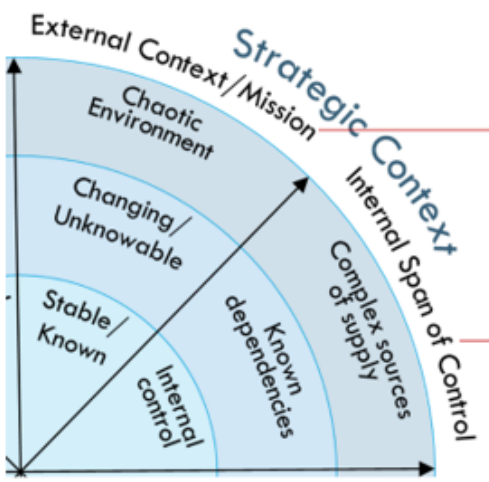


https://www.theuncertaintyproject.org/tools/assumptions-mapping

DEVELOPMENT PROCESS

Historical case studies: reviewed documented lessons learned for questions of uncertainty and assumptions

Current programs: interviewed program management for questions of uncertainty and assumptions (1 program to date)



- **External Uncertainties:** Changing political environment; Changing threat environment; Unexpected events (black swans)
- **Hedges:** Leaders with domain knowledge/expertise; Improved knowledge exchange; Reserves and buffers; Speed of execution
- **Example Analytics:** Budgets – near and out years; Political trends and discussion; Political span of the project; World events monitoring; Polls and interviews

- **Internal Uncertainties:** Hidden data/knowledge; Resource disruptions; Stakeholder conflict
- **Hedges:** Leaders with domain knowledge/expertise; Flexibility in contracting; Incentive structures; Organizing for communication
- **Example Analytics:** Dependency networks; Relationship networks; Continuous improvement tracking; Resource allocations; Team alignment

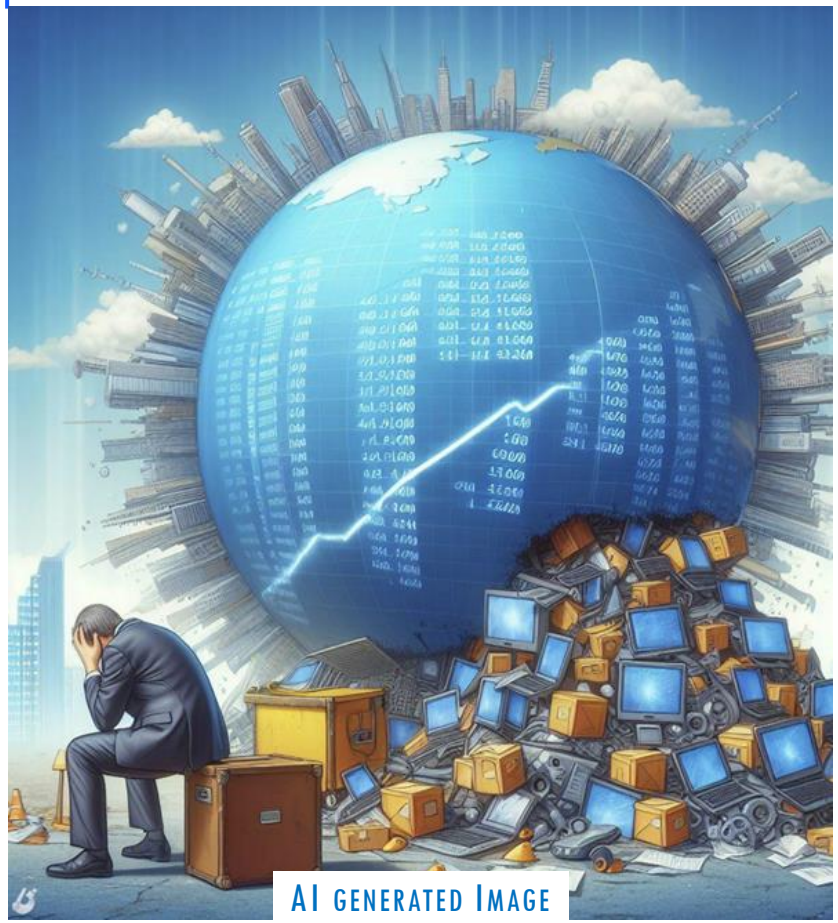
External context/mission:

1. How would you characterize political/funding uncertainties for the program?
2. How certain or uncertain are overall project resources (funding, staffing, etc.)?
3. How aware are senior decision makers of the uncertainties that may affect the program?
4. What external disruptions to the program have you evaluated? In what timeframe?

Internal context/span of control:

1. What are the subcontracting relationships? How is the contract structured?
2. Was a sharing of risk part of the contract structure/down-select criteria?
3. How are contract incentives used and to what tier of the supply chain?
4. How are contractors engaged to address uncertainties as they arise?

Agenda



AI generated Image

12:00 p.m. ET: Project introduction and status

12:15 p.m. ET: A framework to analyze megaproject uncertainty

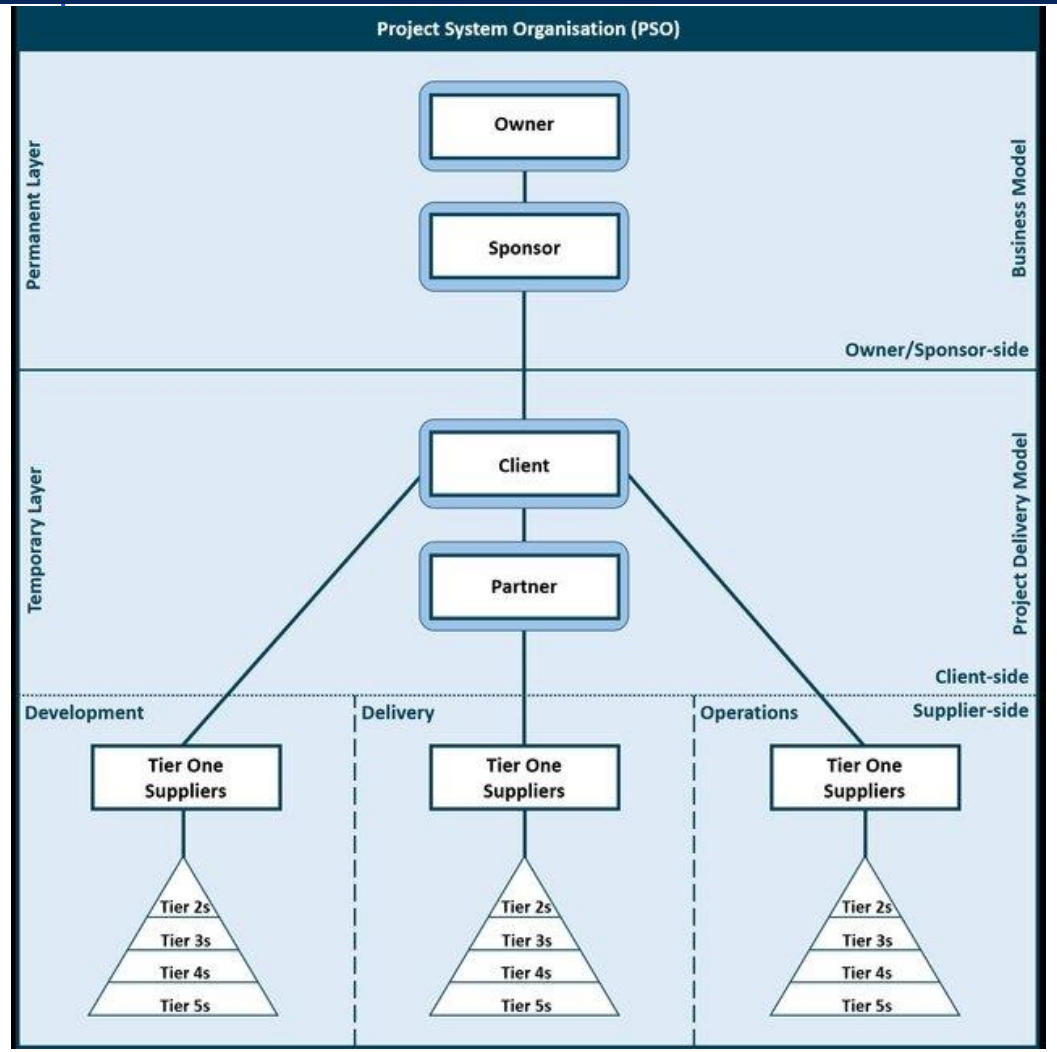
12:30 p.m. ET: Summary of Lessons Learned by category

1:30 p.m. ET: Adjourn

MEGAPROJECT PLAYBOOK: 12 BEST PRACTICES/LESSONS LEARNED FOR MEGAPROJECT MANAGEMENT

1. Establish clarity in the role of "the client"
2. Continuously engage and manage stakeholders
3. Integrate and coordinate across the supply chain, maintain flexibility
4. Use standardized project management processes
5. Decide at the "Last Responsible Moment" (LRM)
6. Plan and define flexible project decision-making behaviors
7. Invest in flexibility to manage risk and uncertainty
8. Invest in digital models and environments for design and project execution
9. Invest in experimentation and test
10. Choose leaders with megaproject skills
11. Maintain and share strategic knowledge
12. Deploy integrated project teams

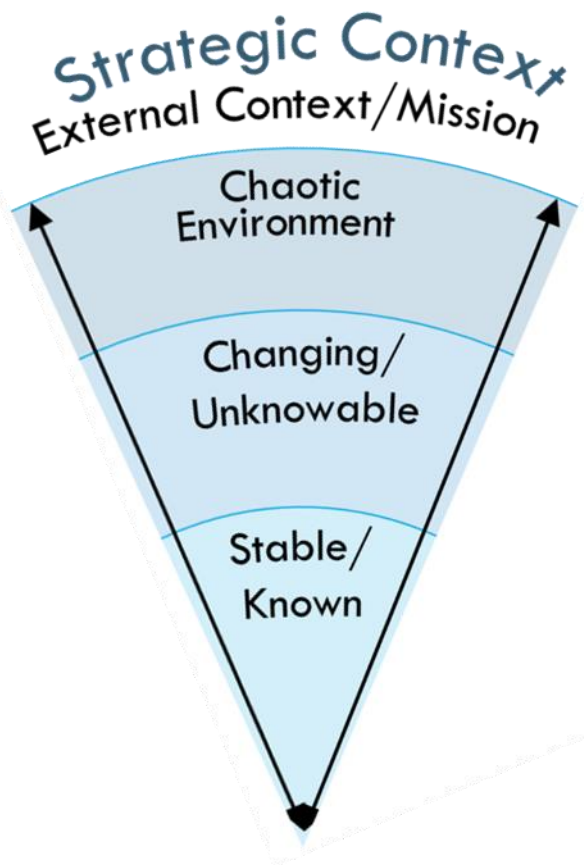
1. Establish clarity in the role of "the client"



Denicol, J., Davies, A. & Pryke, S. (2021). The organisational architecture of megaprojects. International Journal of Project Management. 39.

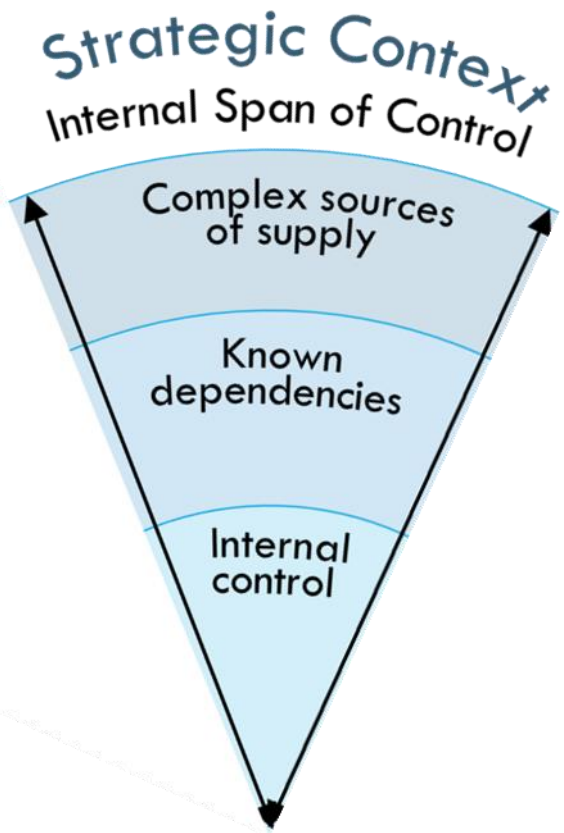
1. There needs to be absolute clarity between the role of the sponsor, the role of the client or "deliverer," and the role of the owner (or operator).
2. Sponsors set the requirements and manage the scope. This often overlaps with the client role because having a budget responsibility drives you into the client area.
3. The client (i.e. delivery authority), is a single-purpose temporary or permanent organization created and empowered by the sponsor to oversee the project.
4. In DoD megaprojects, the government and Lead Systems Integrator (LSI) often jointly perform the client role.

2. Continuously Engage and Manage Stakeholders



1. Megaprojects have a large number of diverse stakeholders, a key function of the leadership team's time is to interface with and ensure all their needs are captured in regular project briefs.
2. Involve key stakeholders in key decisions when they need to be made (see LRM's) instead of at preplanned milestones—this promotes both optimal decision points and stakeholder engagement.
3. Limit dependencies on other projects that are not in the client's control. Use caution when carrying these dependencies across key decision points. Make sure they are mature.
4. Actively test project resilience by running scenarios for "black swan" events.

3. Integrate and coordinate across the supply chain, Maintain flexibility



1. **Client** has a clear role to manage risk and uncertainty and set up a decision environment that will enable project success. Define an integrated leadership and decision processes matching the client role (cross-organizational).
2. Use incremental option-based contracts to co-evolve the project at the client level. The role of or relationship with the client may shift across phases.
3. Develop contracts that centralize risk pools at the client level to keep project funds in play rather than paying for risk up front in subcontracts.
4. Create a standard subcontractor contract for all key players and hold consent at the client level over these contracts.

   The subcontractors also will find that this makes them feel part of the overall project experience.
5. Include in the supplier contracts how incentives and risk pools will be used to jointly solve problems when things don't go to plan.

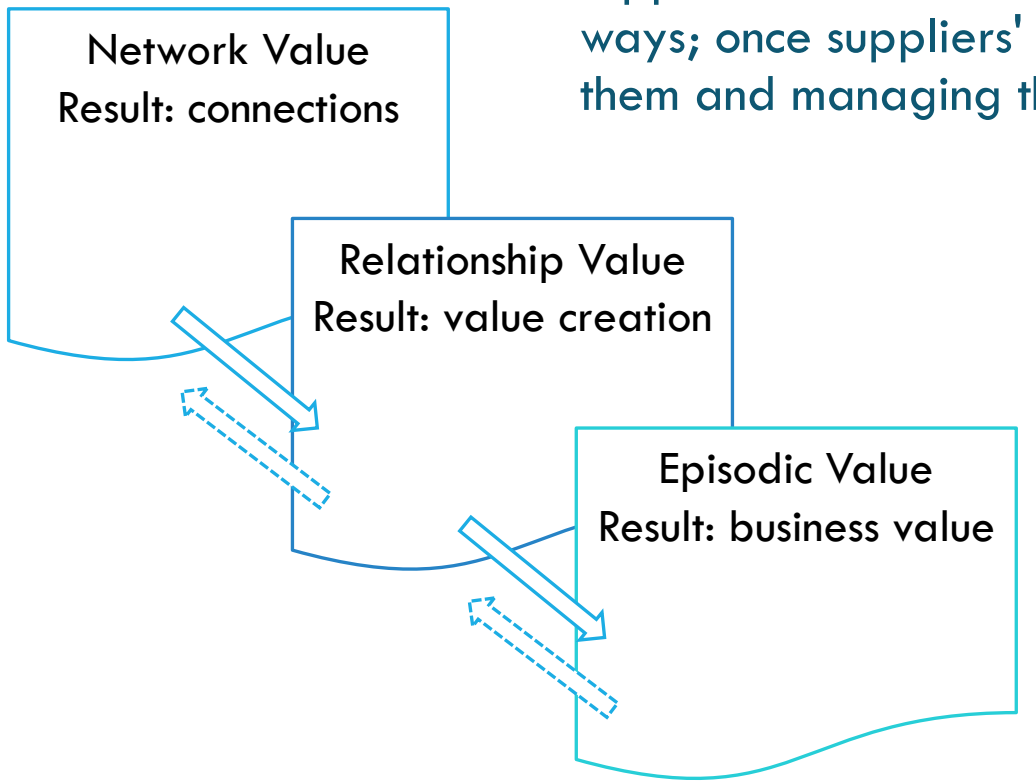
FLRAA: Option-based contracting

T5: Client centralized risk pool

FCS: program structure made it difficult to award the LSI less than all available performance fees

Supplier Mapping Methods and Tools Needed

T5: "Map the motivations of different suppliers and then overlay the different suppliers on the total project. Use this to work with different suppliers in different ways; once suppliers' motivations are understood then trying to get the best from them and managing their fears is more achievable."



Adapted from: Bouzdine-Chameeva, T., Mandjàk, T., & Durrieu, F (2002). Organizational Learning of Business Relationship Value by Means of Causal Mapping, Third European Conference on Organisational Knowledge, Learning and Capabilities, 5-6 April 2002, Athens, Greece

Network Value:

- Cross sector relationships – connectedness
- Importance (centrality)

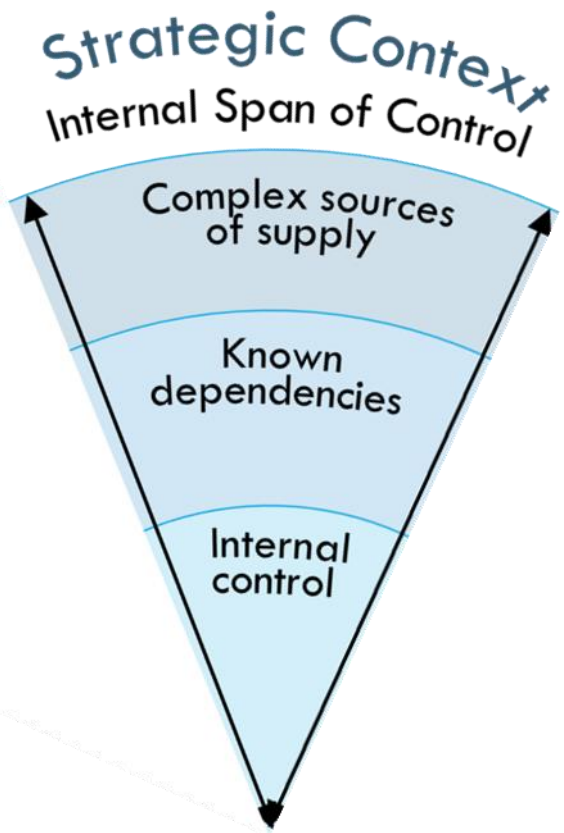
Relationship Value:

- Develop Capability
- Create relational trust
- Focus on joint problem solving
- Align motivation and cooperation

Episodic Value:

- Incentivize cost and technical factors
- Manage risk, safety and security
- Ensure credibility and reputation

4. USE STANDARDIZED PROJECT MANAGEMENT PROCESSES



1. Map teamwide critical schedule milestones and make them visible to all.
2. Each team must have a risk-assessment plan, risk assessments, live risk registers, control action plans and risk and opportunity dashboards. Each team must go through monthly dashboard reviews as part of the program-management cycle.
3. Use earned value management and an integrated schedule. Earned value methods do not predict uncertainties but they do measure the "heartbeat" of the program progress.
4. All supplier key performance indicators should be measured monthly. Corrective action meetings must be held for those who are not performing to team standards. **Do not be afraid to remove suppliers who are not meeting team standards.**

Heathrow T5: "During the project, two first-tier suppliers and about 12 subcontractors were removed."

5. Hold Integrated Baseline Reviews (IBRs) about every six months. Most will find scope gaps that are not currently budgeted.
6. Invest in data and modern data analytics tools to learn much deeper than the reports. (Subject of the next Megaprojects QRF)

5. Decide at the "Last Responsible Moment" (LRM)

The idea behind the Last Responsible Moment (LRM) is simple. Rather than doing everything you need to do all at once, you do something either:

at the point at which you need it, or

at the point at which it would be irresponsible not to do it.

Heathrow T5 conducted "weekly 'surgery' meetings to act as clearinghouse for design decisions since speed of decision is also vital to keeping a project on time."

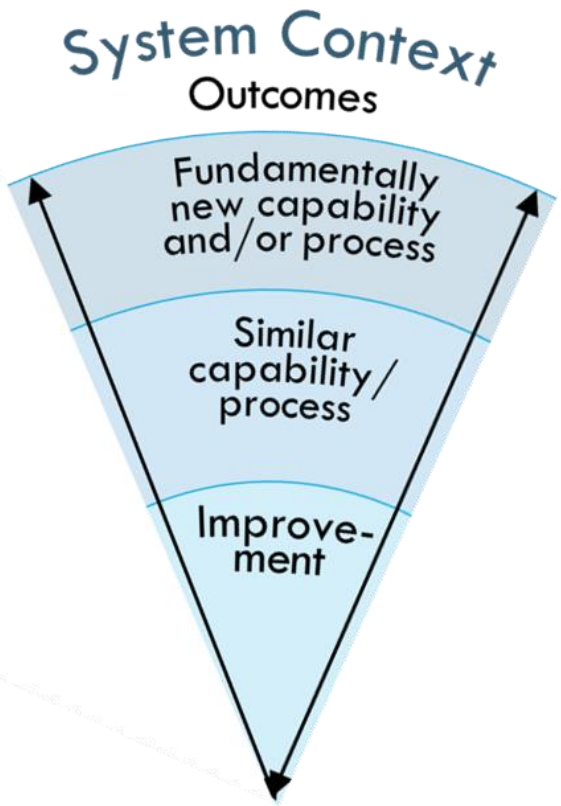
This can be carried out by any discipline and at any phase of a project by asking the questions:

- **do we need to do this now?**
- **do we need to do all of this now?**

You spend less time doing the same work.

Sometimes the LRM never arrives.

6. Plan & define flexible project decision-making behaviors



1. Choose a client who is very experienced in the domain of the project.
2. Maintain a balance between project requirements, technologies, and **affordability** at all phases. Do not carry forward any requirements or technologies unless you have evidence they will be affordable.
3. Develop requirements iteratively, do not freeze requirements prior to the "last responsible moment" but rapidly execute afterward.
4. Develop the design iteratively, do not freeze design prior to the "last responsible moment" but rapidly execute afterward.
5. Maintain user touch points: map and update the map of the user journeys with every design decision.

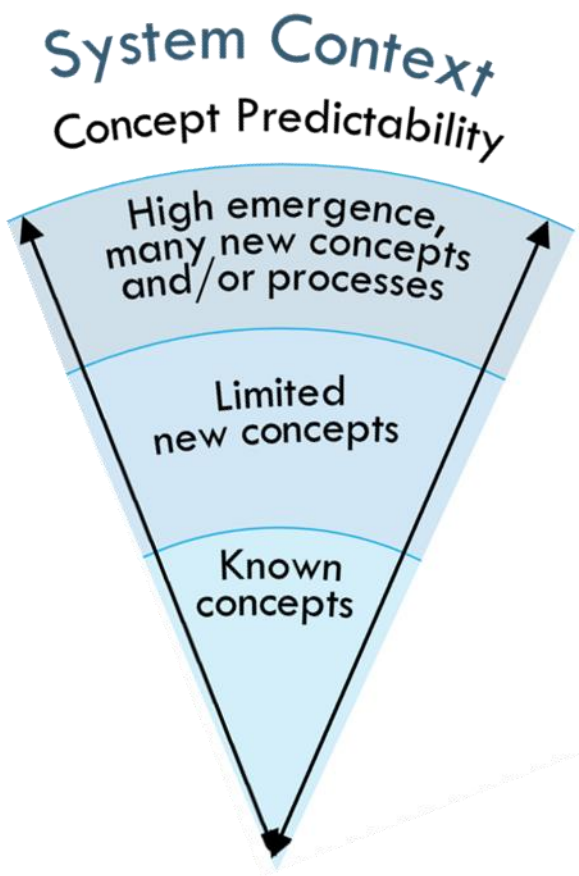
FCS: Boeing/SAIC LSI role outside of traditional Army Combat Systems Domain.

FLRAA: Iterated requirements for affordability and realism to subcontractor capabilities.

SpaceX Starhopper: flexibility in design, iterate in design execution.

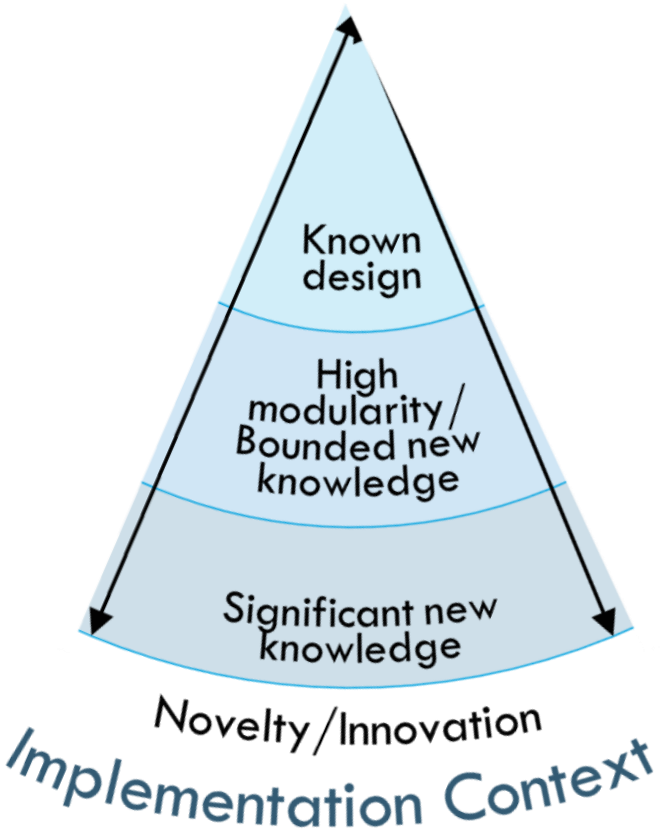
FLRAA: "get the soldier excited" with frequent touch points.

7. Invest in flexibility to manage risk & uncertainty



1. Invest in single modeling environments to allow all design teams to share all data, models, drawings and written design information.
2. Identify key performance drivers and invest in high fidelity models to evaluate and validate performance early.
3. Use multidimensional trades and value engineering to look at what could be simplified or reduced in scope without impacting customer experience.
4. Build predictive models of key parameters in the System Context.
5. **Create guidelines and training that set out the principles of the design for all the team.**

8. Invest in digital models and environments for design and project execution



Deploy modularity

1. Create modularity in design, modularity isolates necessary knowledge.
2. Enforce modularity in build, simplifies integration and test.

FLRAA: over 200 MOSA use cases

Minimize technology novelty

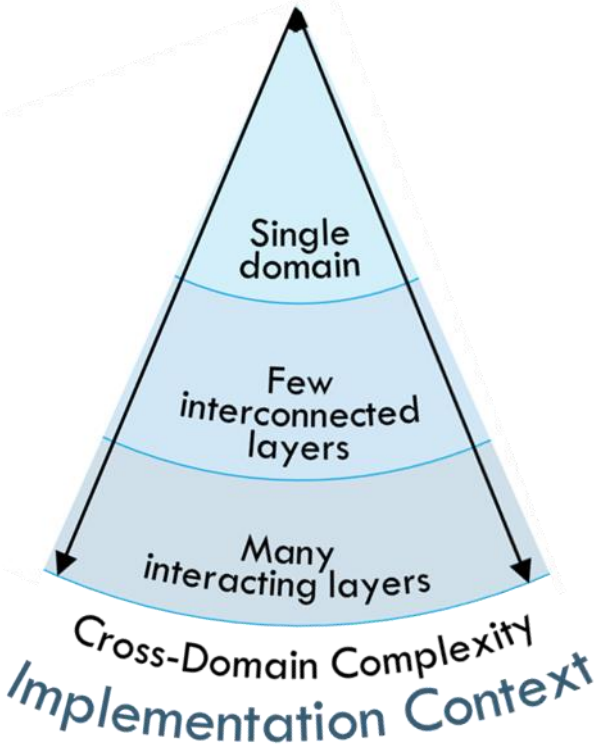
1. Use existing or well-established technologies as much as possible.
2. Do not carry low-TRL technologies past any critical design decision points.
3. Validate critical technologies early with realistic field experiments.

FCS: co-dependent on external JTRS program for operational concept.

FLRAA: TMRR phases

9. Invest in Experimentation and Test

F22: high fidelity models of every subsystem were continuously delivered and used in all test phases.

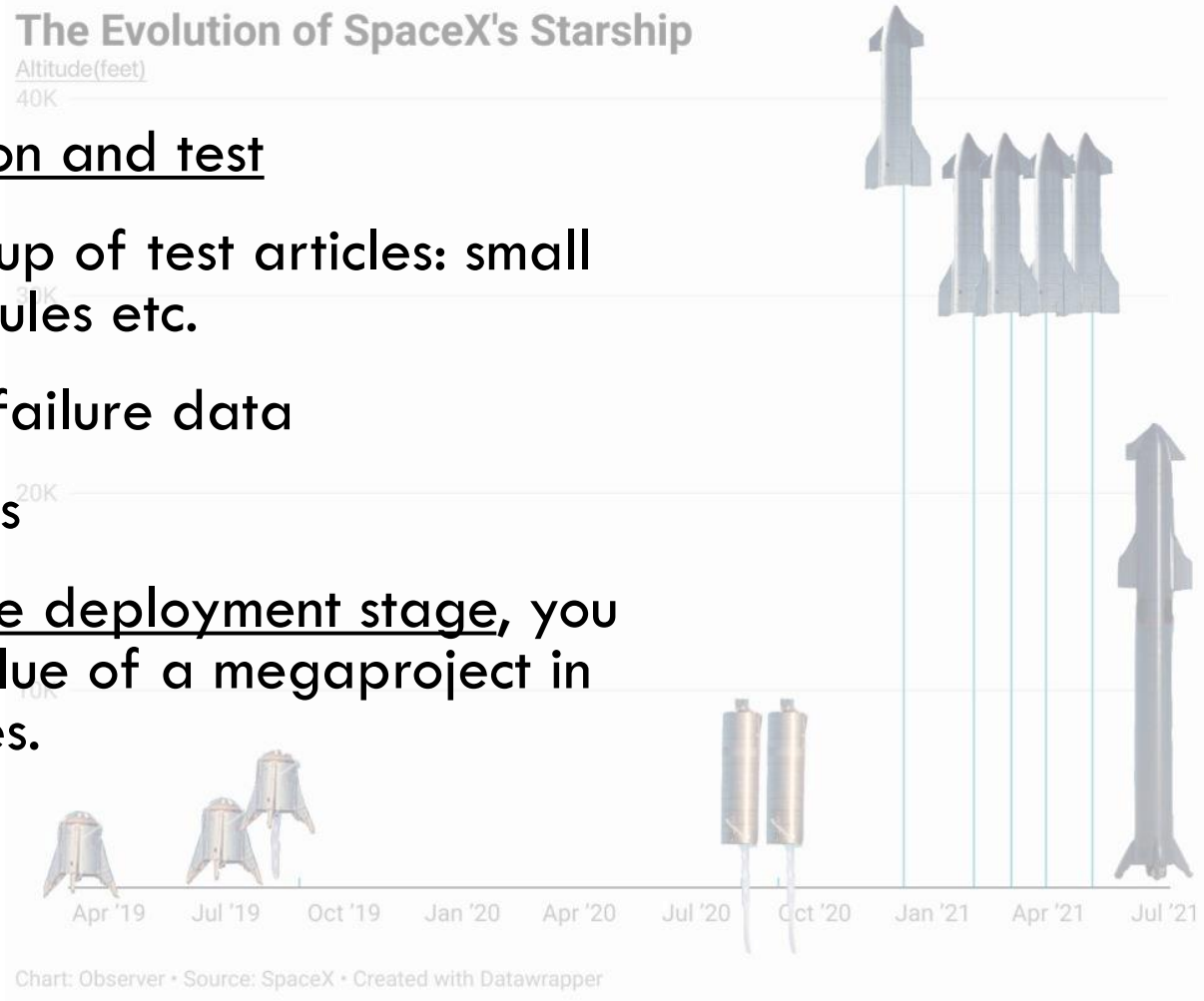


Invest in experimentation and test

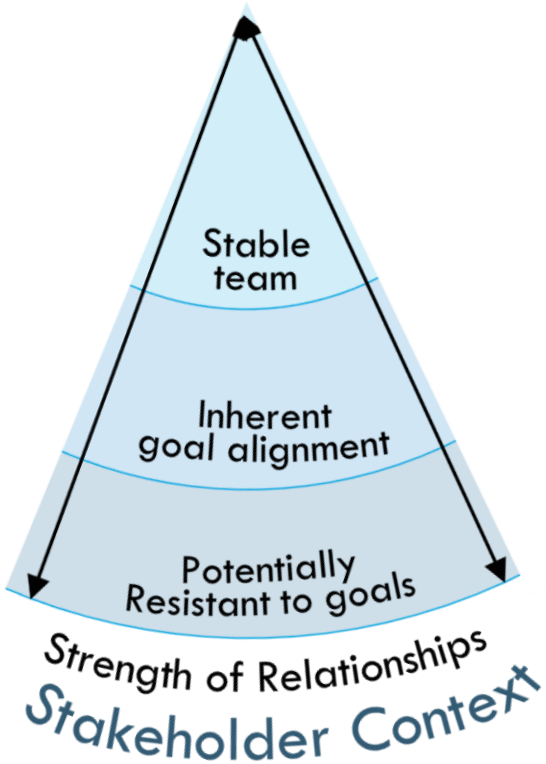
1. Invest in realistic buildup of test articles: small scale prototypes, modules etc.
2. Test to failure, collect failure data
3. Test to validate models

Plan for flexibility in the deployment stage, you cannot know the full value of a megaproject in the development phases.

T5: The roof section trial assembly exposed 125 errors that would have slowed progress on site.



10. Choose leaders with megaproject skills



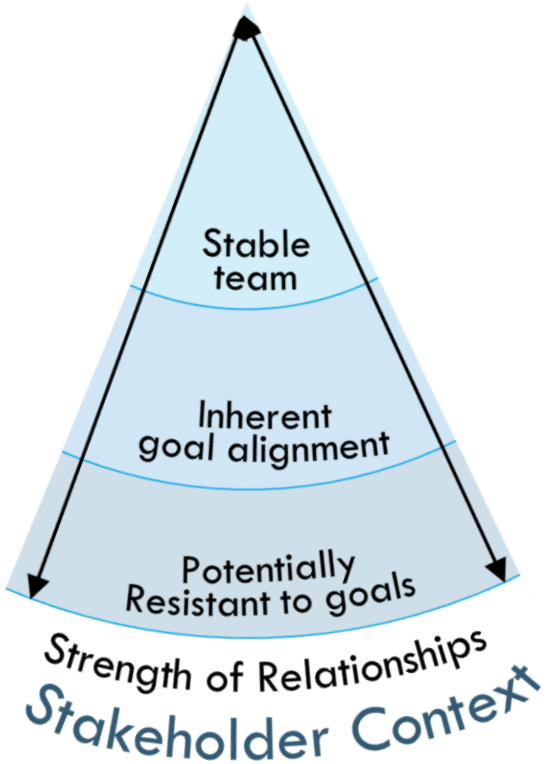
10/100/1000 rule from Heathrow T5:

"10 senior leaders whose personal presence, vision and good judgement put the project on a course for success, often challenging existing industry norms.

Another 100 leaders who by making critical differences, taking brave stands, interpreting new ideas and frameworks, leading by example, and ultimately creating an operating environment that enabled others to be successful.

Another 1000 leaders who given that context were able to swim with the tide and do their leadership role in a demanding workplace that had little space for error."

10. Choose Leaders With Megaproject Skills



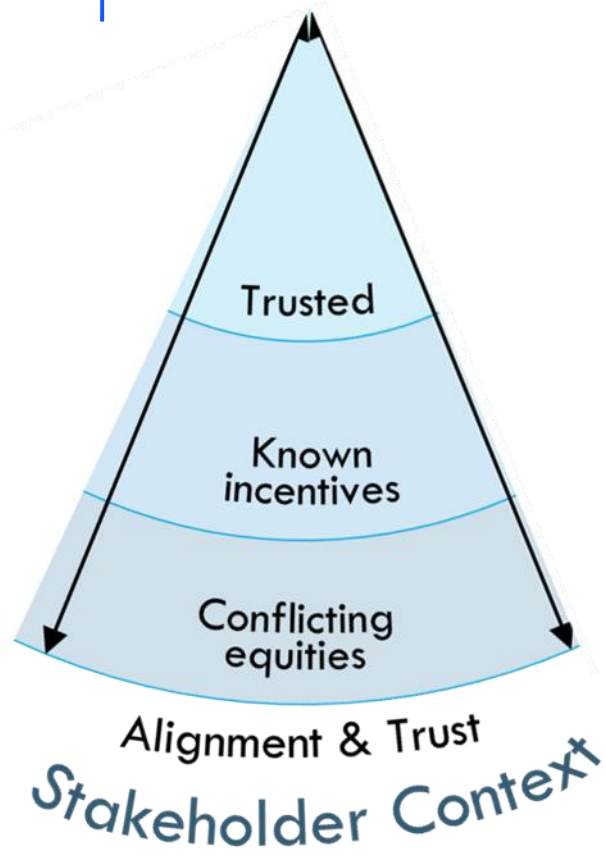
1. Select leaders from among the best in the world to create a joined-up experience. In megaprojects, a team with a wide range of diverse skills provides its real strength.
2. Team experience should come from different sectors based on critical strengths in each sector and what they can bring to the project. Educate across domains. Each domain should have leadership responsibility on the project.
3. Senior leadership must never panic. There must be a great belief in the ability of the team to solve any problem thrown at them.
4. Select leaders who are highly aware of their own abilities for learning.
5. Rigorously assess the capabilities of the leadership.

   Select/train leaders who spend less time on work processes and more time on people management, alignment, and communications.

   Select/train leaders who promote psychological safety, debate, innovation from anywhere, and knowledge transfer.

   Select/train leaders who balance control and flexibility, challenge over-optimism and misrepresentation.

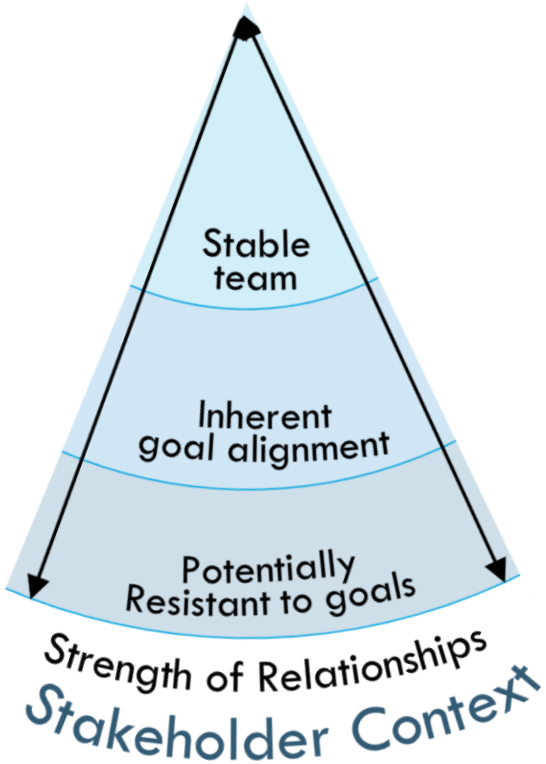
11. Deploy integrated project teams



1. Keep the primary user teams resident in the program office
2. Also collocate internal functions (safety, security, etc.) and external statutory users (security, compliance)
3. Get the user excited and include user touch points in the program strategy.
4. All parties work as one team instead of a collection of separate project groups. **Develop a 'winning teams' toolkit and educate and support people on the 'what' and 'how' of working together.**
5. Make it clear to people that they will be asked to leave (the project) if they do not operate to team behavioral norms.

11. Maintain and share strategic knowledge

T5: "The message of being on time, on budget and delivering a quality program safely must run through all the channels and all of the verbal messaging."



1. Conduct regular strategic knowledge sharing events for task definition and scheduling. The team will value the openness and clear structure, and the fact that there were places where information would be shared and genuine debate could take place.
2. Maintain and share strategic knowledge across all critical stakeholders as a holistic project reference book.
3. Encourage early identification of changes through a system where anyone can raise an early warning notification to alert management to a potential issue before the decision was completed.

33

My Yr2000 Complex Program Management Process

Avionics team leads

Empowered representatives from all dependent teams

Continuity across program

Tied to their home offices

Empowered to make decisions

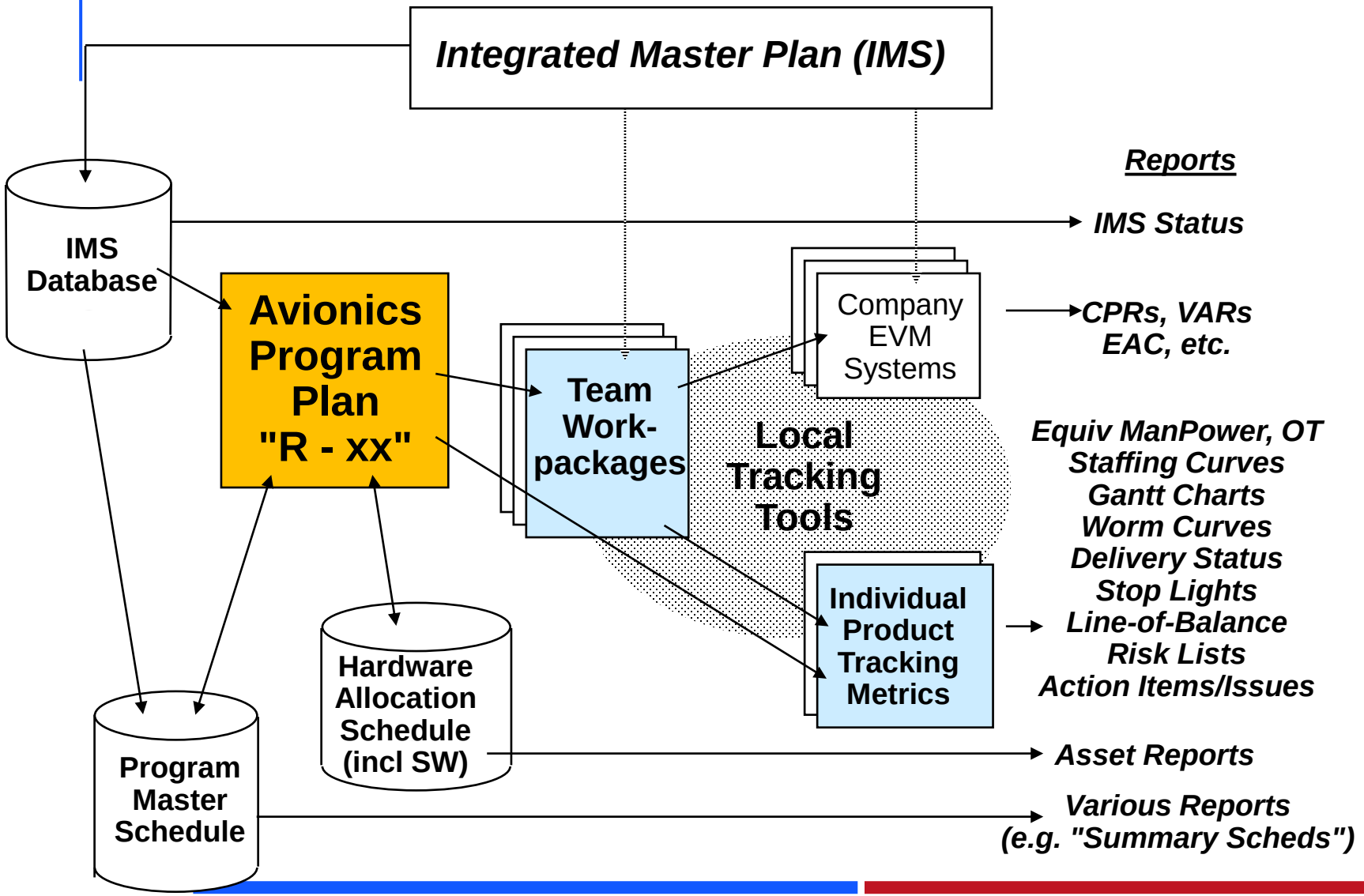
No one leaves until plan is put back together

Results collected in Avionics Program Plan Rxx+1

- Who are the primary decision agents, and in particular who can copy strategies from whom?

Axelrod, R. and Cohen, M. 2008. Harnessing Complexity. Basic Books.

My Yr2000 Complex Program Management Process



- The "Avionics Program Plan"
- Central to managing complexity
- "Book of Knowledge"
- Version 23 at First Flight
- Managed by an empowered leadership team
- Shared visualization of data, information and knowledge

Agenda

12:00 p.m. ET: Project introduction and status

12:15 p.m. ET: A framework to analyze megaproject uncertainty

12:30 p.m. ET: Two historical case studies:
Heathrow Terminal 5
Army Future Combat Systems

12:50 p.m. ET: Visualization framework

1:20 p.m. ET: Leadership framework

1:30 p.m. ET: Wrapup and Adjourn

CONTACT US:
airc@acqirc.org

ACQIRC.ORG