SYSTEMS ENGINEERING FORUM

Designing for Principles: An Alternate Capability Development Approach

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Workshop Overview (13 May)

- **Title: "Designing for Principles (DfP): A More Agile Approach to Capability Development"**
  - An exploration of the DfP Concept and its suitability as a novel capability development approach in highly uncertain environments. Specific recommendations and examples are focused on the newly created USSF, but applicability of tenets and techniques are broader.
- **Participants**
  - Diverse set of stakeholder orgs represented, including OSD, NASA, NRO, and USSF
- **Three Main Goals**
  - Understand the DfP capability development approach
  - Assess viability and suitability of the DfP capability development approach
  - Determine way forward

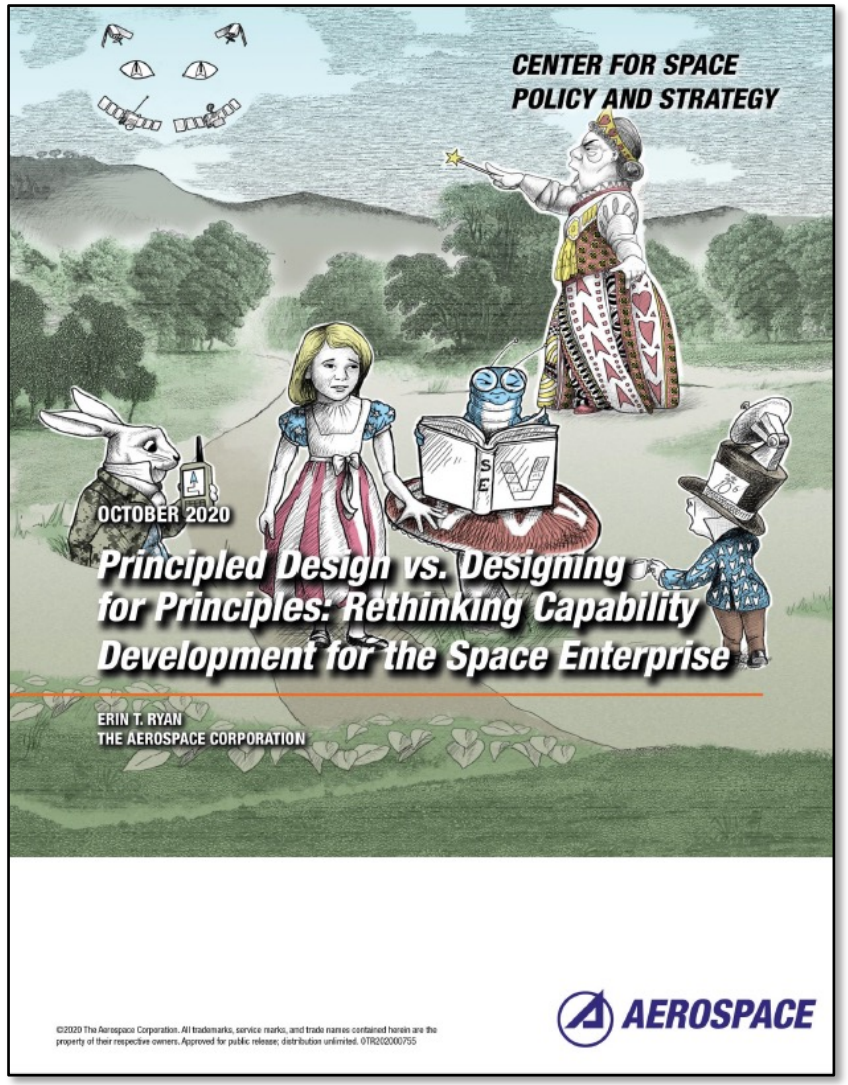
Workshop Agenda

DURATION	TOPIC	Lead
5 mins	Welcome / Intro / Logistics	Ryan
10 mins	Participant Introductions	Group
60 mins	Part 1: What Is DfP?	Ryan
10 mins	[BREAK]	-
20 mins	Open Discussion regarding DfP Concept	Group
30 mins	Part 2: Implementing DfP (The 24 Recommendations)	Ryan
30 mins	Open Discussion Regarding Implementation	Group
15 mins	[BREAK]	-
30 mins	Where Do We Go?: Work Needed to Mature DfP	Group
30 mins	Where Do We Go?: Viability/Applicability of Recommendations	Group
10 mins	[BREAK]	-
45 mins	Implementation Steps / POAM development	Group

PART 1: What Is Designing for Principles?

Designing for Principles Paper 1

- ***"Principled Design vs. Designing for Principles: Rethinking Capability Development for the Space Enterprise"***
  - Published by Aerospace Center for Space Policy and Strategy in Oct 2020
- **Key Takeaways**
  - Describes an alternate capability development approach relative to traditional Systems Engineering methodology
  - Intended to challenge the paradigm of many core assumptions of current approach to DoD space capability development
- https://aerospace.org/paper/principled-design-vs-designing-principles-rethinking-capability-development-space-enterprise



The DfP Story in a Nutshell

1. ***The traditional SE methodology (i.e., "Principled Design") has served the DoD well for many decades, producing exquisite systems that deliver critical defense capabilities***

2. ***However, SE has some inherent weaknesses, and in situations characterized by greater uncertainty/complexity, SE techniques are particularly prone to failure***

3. ***At a certain level of uncertainty/complexity, it makes more sense to exchange the rigorous "Principled Design" approach of SE for one that is better suited for valuing and driving design principles such as flexibility and adaptability***

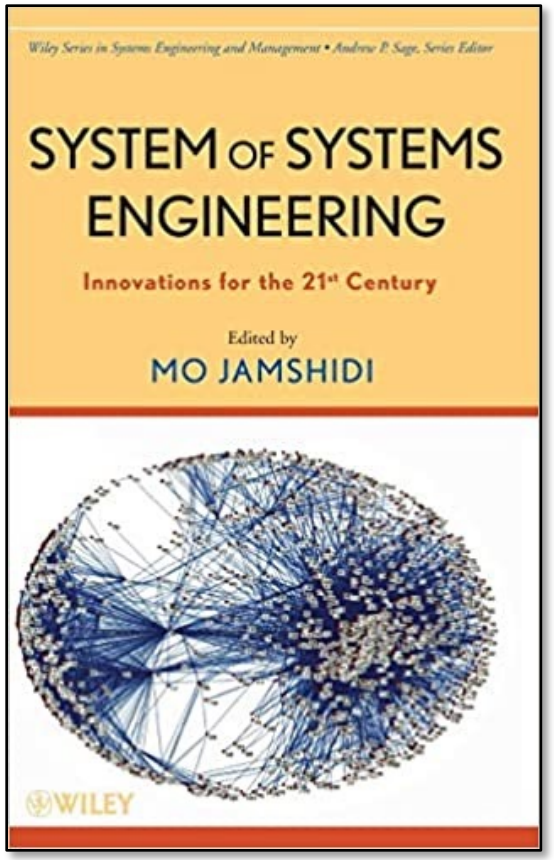
4. ***By extending and generalizing an existing methodology known as Design for Changeability, we can establish a more robust and useful capability development framework: "Designing for Principles (DfP)"***

5. ***DfP serves as a starkly different approach to Principled Design that is inherently better suited for environments and applications characterized by high uncertainty/complexity***

The World is Fundamentally Different

…twenty-first century engineering is witnessing an unprecedented change in the way we conceive, develop, field, and sustain systems. Many of the premises underlying the traditional systems engineering (SE) strategies are no longer valid. Traditional SE has been focusing on developing stand-alone systems with stable architecture and static technology base in which improvements were slow and very costly. These strategies incorrectly assume that all of the systems of systems requirements are known in the beginning of the development process and can be frozen in time or assumed to be stable. The traditional SE strategies also wrongly assume that the concepts of operation and various technologies used for constructing today's SoS are static and are subject to minor future changes.

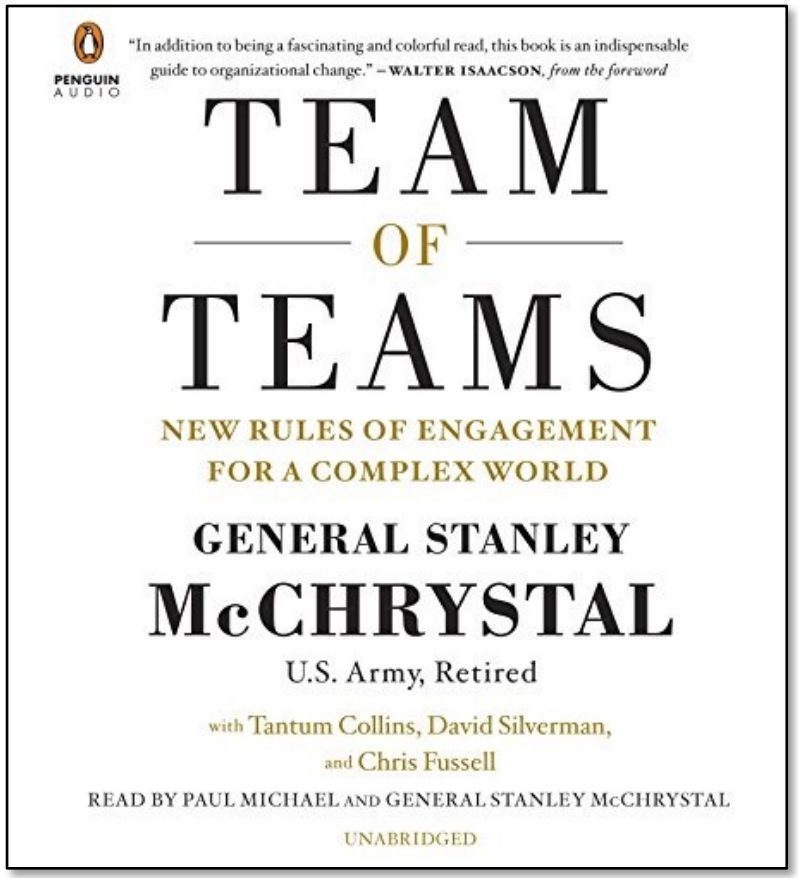
– "Systems of Systems Engineering," Mohammad Jamshidi



Complexity Changes the Game

- **"Complicated" vs. "Complex"**
  - Complicated systems can generally be decomposed whereas complex systems typically cannot
  - Gestalt of complex systems means behavior of whole cannot be reliably discerned by summing the parts

> *Complexity produces a fundamentally different situation from the complicated challenges of the past; complicated problems required great effort, but ultimately yielded to prediction. Complexity means that, in spite of our increased abilities to track and measure, the world has become, in many ways, vastly less predictable. This unpredictability is fundamentally incompatible with reductionist managerial models based around planning and prediction. The new environment demands a new approach.*
>
> – "Team of Teams," General Stanley McChrystal



Designing for Principles Pillars

1. **Don’t Be Obsessed with Requirements**

   Reduce total number of requirements, use objectives in lieu of requirements, and prioritize non-functional requirements over functional requirements

2. **Keep the Big Picture In Mind**

   Emphasize broader perspective of capabilities over systems and extend thinking to all facets of development, including performance, resilience, and risk

3. **Embrace and Understand Uncertainty**

   Uncertainty is not to be feared; recognize that nothing is as certain as we think and to pretend otherwise is myopic and counterproductive

4. **Go Fast**

   Prioritize speed of capability development to supplant the pernicious “stagnation” cycle with self-reinforcing “celerity” cycle that embodies and enables agility

Traditional SE vs. DfP (Generic Comparison)

Design Element	Traditional SE ("Principled Design")	DfP-Based Approach ("Designing for Principles")
Technical Performance	Optimized for known functional/performance requirements; best option if current circumstances/ assumptions remain valid	Reduced performance relative to current circumstances/assumptions, but generally superior performance for broader range of possibilities; emphasizes non-functional requirements, i.e., "-ilities"
Requirements	Large #, specifying as much as possible, including thresholds of acceptable performance; overarching question is "Do we have everything we need?"	Fewer in number, or not used; specify only what matters and prioritize objectives over traditional requirements; overarching question is "Do we need everything we have?"
Interfaces	Highly integrated with tight coupling between elements; functionally monolithic; intra-system interfaces are the focus	Modular/interoperable with loose coupling between elements; functionally disaggregated; inter-system interfaces are the focus
Resilience to *Known* Threats	Typically on major systems; assumes that if all systems meet their allocated requirements, the enterprise will perform as the sum of its parts	May be at any level, but typically on SoS or the enterprise; assumes emergent behavior and recognizes that "-ilities" can generally best be met at the enterprise level
Resilience to *Unknown* Threats	Extremely low (only by pure chance) because approach is inherently threat-centric	Moderate; flexible implementations foster ability to survive broader range of threats, even if not anticipated; approach is more threat-agnostic
Summary	Reactive, downplays uncertainty & assumes stability in resources, rqmnts, & threats. Emphasis is on near-term, exquisite technical performance and efficiency.	Proactive, embraces uncertainty and expects the unexpected. Emphasis is on networked adaptability and long-term "good enough" technical performance.

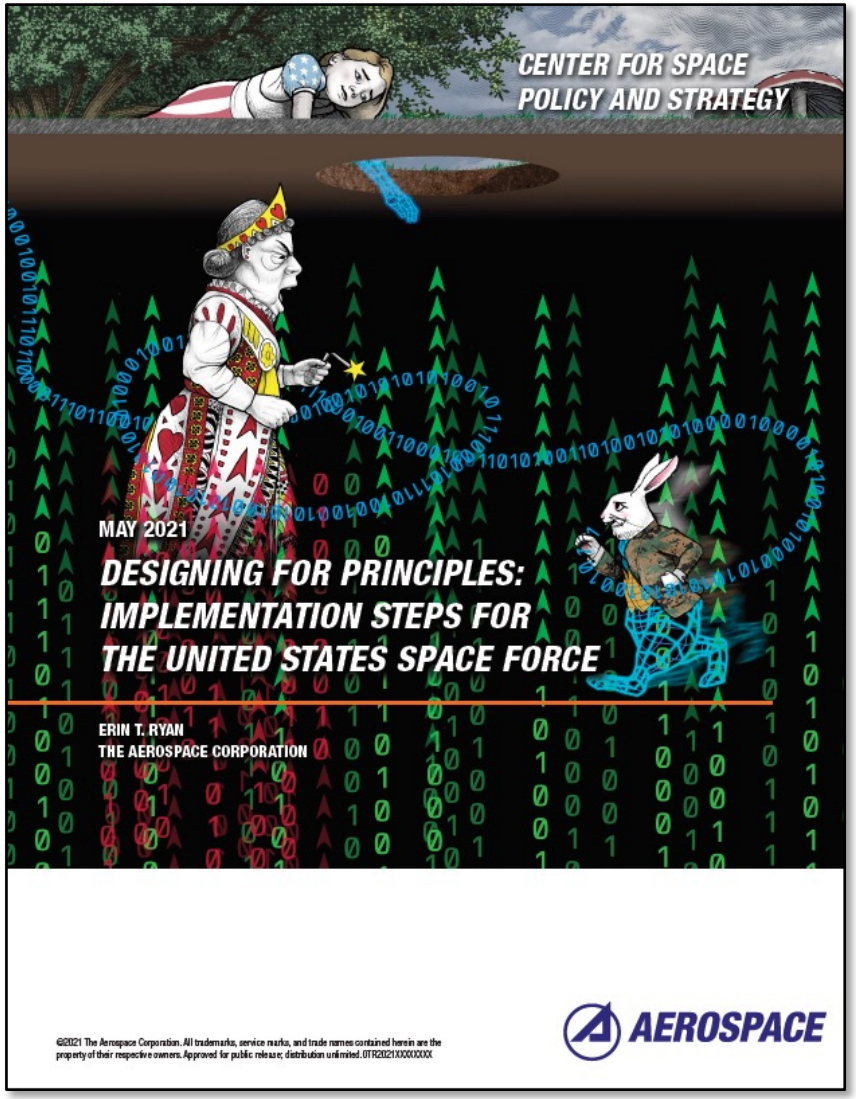
Traditional SE vs. DfP (Space Design Comparison)

Design Element	Traditional SE ("Principled Design")	DfP-Based Approach ("Designing for Principles")
Space Architecture	Emphasis on small # of large, monolithic satellites working independently; # of satellites fielded is no more than absolute minimum necessary to meet rqmnts.	Emphasis on large # of smaller satellites working cooperatively; more satellites are fielded than necessary in order to support contingency/reserve capacity.
Ground Architecture	Ground sites are large, but few in #; sites are also fixed in location w/ ability to support a limited # and/or type of satellites; each site operates independently. Number of ground sites is no more than absolute minimum necessary to meet rqmnts.	Ground sites are smaller, but greater in #; sites are physically mobile, geographically distributed, or functionality distributed to support a large number and/or type of satellites; ground sites are interoperable and purposely exceed minimum rqmnts to support contingency/reserve capacity.
Satellite	Satellite bus, primary payload, and associated subsystems are tightly integrated and optimized to achieve *maximum* technical performance. Mass of satellite is minimized thru custom interfaces, de-prioritization of SWaP, and minimal propellant.	Satellite bus, primary payload, and associated subsystems are loosely coupled to achieve *acceptable* performance. For larger satellites, mass is minimized through reduced technical performance, though offset by modular/standard interfaces, prioritization of SWaP, and additional propellant.
Ground Site	Each site is highly capable and optimized for a specific mission; ops personnel are focused on that mission. Facility planning seeks to minimize physical footprint and using space as efficiently as possible.	Each site is less capable but able to support mult missions; ops personnel are trained to support mult missions as well. Facility planning less concerned w/ physical footprint or using space efficiently; prioritizes dual use and ready expansion.
Communication Architecture	Communication pathways are reliable but fewer in number and type and dedicated to a particular mission; bandwidth is based on current capacity needs.	Individual communication pathways less robust / reliable, but are greater in # and type (e.g., crosslinks, dual-pathing) and mission applicability; bandwidth capacity is greater than currently needed.

PART 2: Implementing Designing for Principles (in the USSF)

Designing for Principles Paper 2

- ***"Designing for Principles: Implementation Steps for the United States Space Force"***
  - Published by Aerospace Center for Space Policy and Strategy in July 2021 [TBD]
- **Key Takeaways**
  - Series of interrelated recommendations (and associated rationale) to implement DfP across the USSF, along w/ designated actors
  - Expansive scope that touches on requirements, resourcing, acquisition, personnel, risk, DE



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Implementation Recommendations, Pillar 1
Don't Be Obsessed with Requirements

1. **Objective-Based Capability Development**
   - Use objectives in lieu of rqmnts for higher level needs; minimize total # of top-level rqmnts
2. **Continuous User Engagement**
   - Formally establish extensive, ongoing dialog between developers & customers to ensure continued validity of objectives
3. **Rapid Incremental Development**
   - Ensure that developers frequently deliver beneficial capability increments
4. **Pervasive Competition**
   - Extend formalized competition between development contractors to more program types & more program phases
5. **Enterprise Requirements**
   - Establish mandatory set of non-functional rqmnts nominally applicable to every system & service in the enterprise
6. **Non-Functional Requirements**
   - Define every NFR and establish corresponding method of quantification, to include associated metrics for inclusion in enterprise value models

Implementation Recommendations, Pillar 2
Keep the Big Picture in Mind

1. **JROC Strategic Focus**
   - Validate joint capability need only & allocate capability increments to Services along w/ interoperability rqmnts
2. **Architecture-as-a-Service (AaaS)**
   - Establish the force-multiplying functions that every mission needs & provide these as common enterprise services
3. **Service-Wide Resource Authority**
   - Grant CSO multi-year, comprehensive TOA for MFP 12, commensurate w/ command authority
4. **Accountability by Capability**
   - Realign central mgmnt accountability away from programs to broader portfolios of capabilities
5. **Prioritize the Foundational Capabilities**
   - To realize AaaS, strategic resourcing priority must pivot to the enabling infrastructure
6. **Digital Service**
   - Seize the generational opportunity to leverage digital approaches for more agile capability development, particularly wrt implementation of DE

Implementation Recommendations, Pillar 3
Embrace and Understand Uncertainty

1. **Holistic Uncertainty**
   - Conduct comprehensive UM that simultaneously accounts for both risks & opportunities in an integrated fashion
2. **Uncertainty is Uncertain**
   - Use joint probability distributions for relevant sources of uncertainty and incorporate temporal phasing
3. **Informed Decision-Making**
   - Ensure process supports decision analysis thru valid, data-driven techniques to cope w/ all types of uncertainty without distortions
4. **Operational Risk / Uncertainty**
   - Expand consequence considerations beyond programmatics to incorporate user preferences & threats
5. **Capability-Level Uncertainty Management**
   - Take more strategic approach to UM by having capability managers look across portfolios of programs
6. **Personnel Incentive Structure**
   - Align individual conceptions of success to enterprise conceptions of success to promote innovation and smart risk-taking

Implementation Recommendations, Pillar 4
Go Fast

1. **Schedule Preference**
   - Break out of the current stagnation cycle by prioritizing schedule over technical performance
2. **The Celerity Cycle**
   - Embrace the positive cycle that feeds on itself to go increasingly faster, stoke innovation, and infuse the principles of DfP across every corner of the enterprise
3. **Exquisite Avoidance**
   - Prioritize larger #'s of smaller platforms; recognize that extremely high system reliability/longevity are not desirable
4. **Agile Software**
   - Institute Agile software methodology and DevOps to rapidly field capability increments and maintain tight linkage between development and operations
5. **Agile Hardware**
   - Adopt MOSA and apply Agile principles to HW and associated development and manufacturing to keep pace w/ SW
6. **Rapid Acquisition**
   - Use authority granted by Congress to go faster and have every program, by default, be designated as a Rapid Prototyping or Rapid Fielding MTA

Major Findings

- **Broad consensus on the need for change and recognition of problems we have with current capability development process in general, and SE more specifically**
- **Recognition that more work is needed to mature DfP into a true methodology**
- **DfP does challenge some core premises of how DoD SE works, but there was agreement that traditional SE would not go away soon or entirely**
- **DfP is better suited to higher-level strategies and architectures / enterprises / SoS**
- **Several implementation challenges, including**
  - No single champion, interrelated recommendations, senior level advocacy/action
  - Limited applicability to program-level pathfinders / prototypes
  - Significant paradigm change that threatens some sacred cows

Next Steps?

- **Some portions of DfP implementation are underway (coincidentally)**
  - E.g., enterprise requirements, Section 804 acquisition, Capability Development IPT, agile hardware (CPA), capability proliferation, Digital Service, Guardian strategy
- **Additional efforts that involve DfP**
  - Integration with Strategic Foresighting
  - SWAC/FDIO engagement
- **Specific activities that could be pursued to mature / validate DfP**
  - Overhaul of DOD Risk Management Guide
  - Quantification of NFRs
  - Formalize Enterprise Requirements

The Committee remains concerned that the Air Force has not taken more aggressive action in addressing longstanding space acquisition issues and has made little progress in defining what the Space Force will be doing that is fundamentally different than when it was a component of the Air Force.

- HAC-D Report on the FY22 Defense Appropriations Bill