# Small Satellite Reliability Initiative TIM-4

SUBCOMMITTEE ON BEST PRACTICES

# Subcommittee Members

| Name | Organization |
|---|---|
| James Cockrell | NASA |
| Pat Beauchamp | NASA |
| Mike Campola | NASA |
| Jamie Cutler | Univ. of Michigan |
| Ken Hyatt | Adcole MAI |
| Florence Tan | NASA |
| Linda Fuhrman | MIT/LL |
| Hannah Goldberg | Gomspace |
| Charlie Jacka | AFRL |
| Lee Jasper | SDL |
| Mike Johnson | NASA |
| Elizabeth Klein-Lebbink | The Aerospace Corp. |
| Kevin Klein | Vorago Technologies |
| Anthony Diventi | NASA |
| Dan Perry | The Aerospace Corp. |

| Name | Organization |
|---|---|
| Jesse Leitner | NASA |
| Jim Loman | SSL MDA |
| Charles Hymowitz | AEi Systems |
| Chris Mattman | NASA |
| Miquel Moe | NASA |
| Ryan Nugent | Cal Poly San Luis Obispo |
| Patrick Phelan | SwRI |
| Robbie Robertson | Cubic Aerospace |
| Harald Schone | NASA |
| Doug Sheldon | NASA |
| Erica Sullivan | LANL |
| David Petrick | NASA |
| **Catherine Venturini** | **The Aerospace Corp.- Lead** |
| Bruce Yost | NASA |
| David McComas | NASA |
| Scott Horner | NASA |

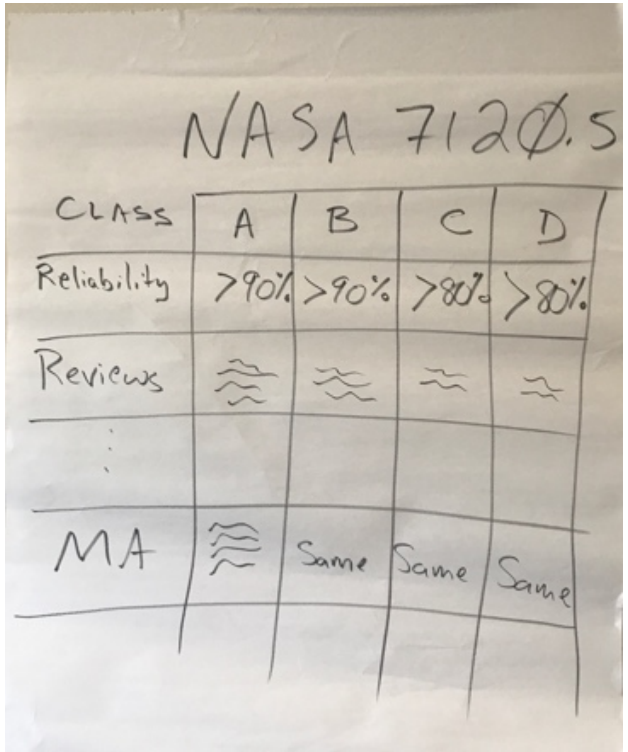
# Background

- Address SmallSat Mission Confidence via Two Concurrent Approaches
  1. **Best Practices and Design/Development Guidelines (the focus of this session)**
  2. Knowledge Sharing  (to be discussed tomorrow)

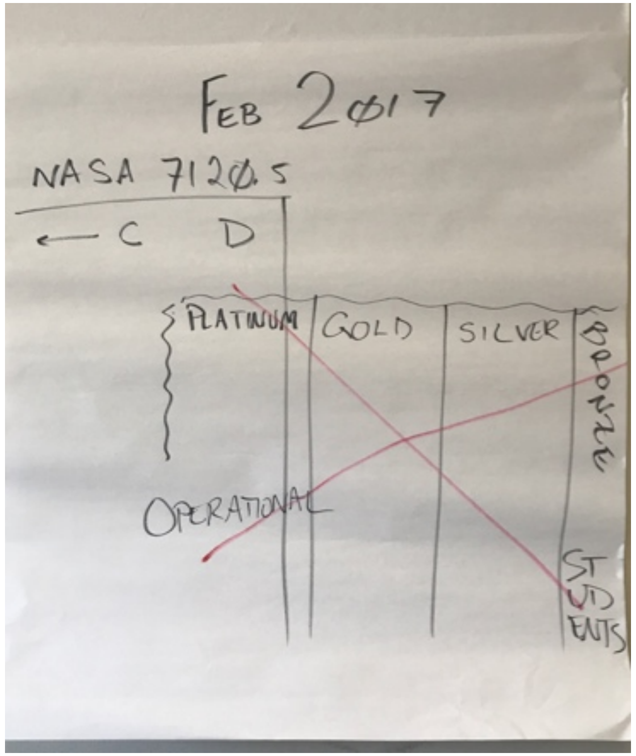
- Target a Broad User-Base

# Background

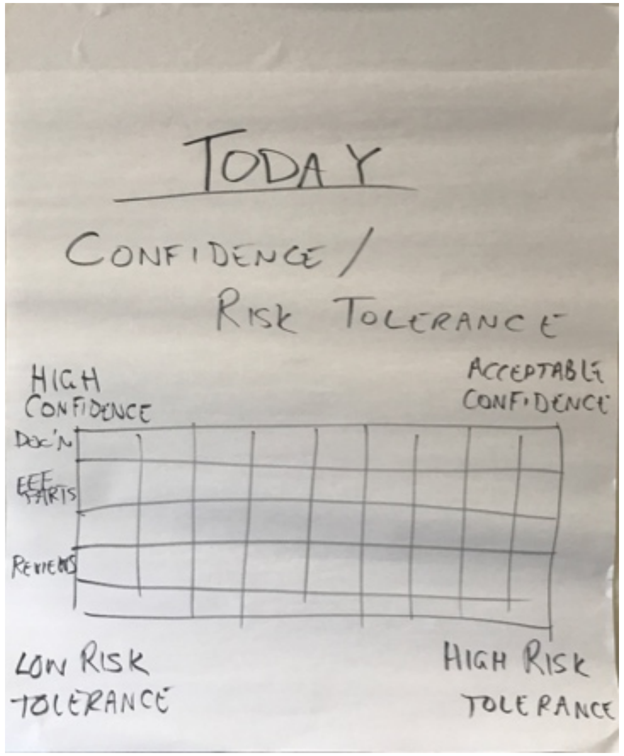
- Question: How to Address *Best Practices and Design/Development Guidelines*?




NASA Classes A-D?  **NO**.




Gold, Silver, Bronze classes?  **NO.**

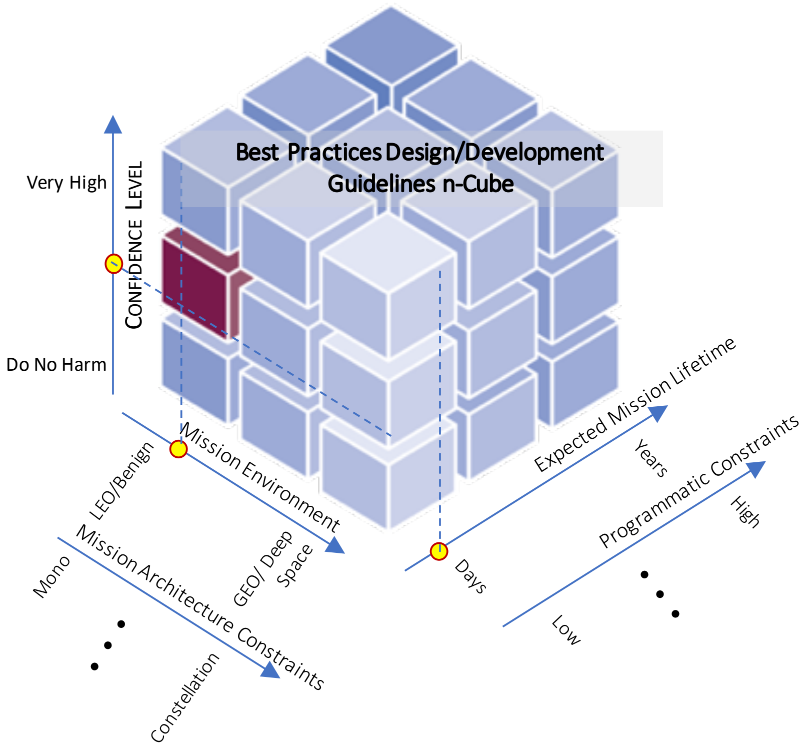



SmallSat Mission Confidence?  **Yes.**

Flipcharts from SSRI TIM-2, December 2017

# Subcommittee Goals as a Result of TIM-3

- Capture best practices and design choices in a mission confidence framework with a constraint driven approach
- This approach highlights the trades required to increase mission confidence with respect to cost, schedule, performance, and risk.
- Created outline with 5 major sections
  1. Getting Started
  2. Expected Mission Lifetime
  3. Space Environment/Orbital Constraints
  4. Programmatic Constraints
  5. Mission Architecture Constraints
- Knowledge would be presented to users via an effective, intelligent software framework (to be discussed this afternoon)



# Section 1: Getting Started

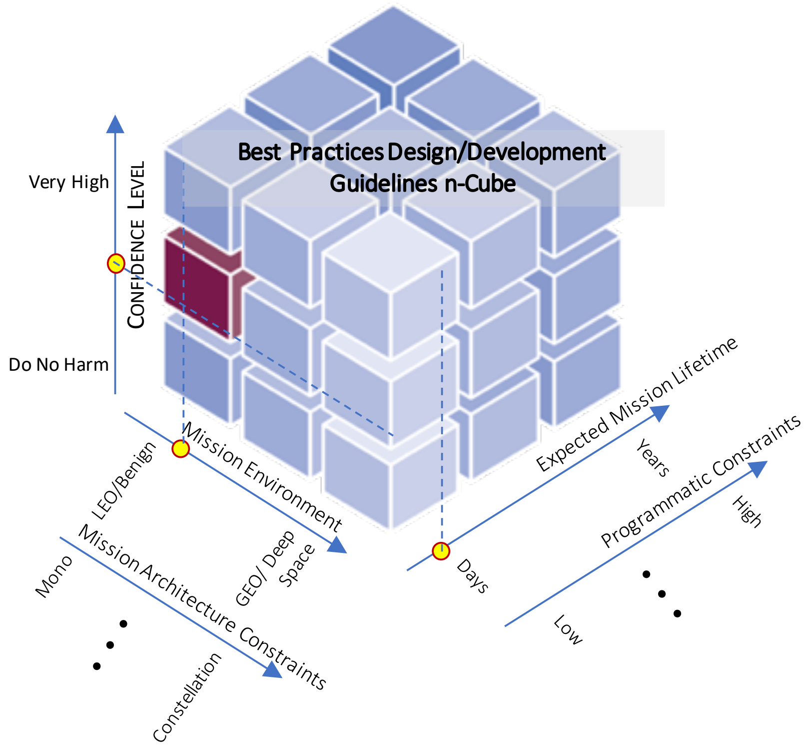
1. **Confidence Level**
   - Identify the targeted mission confidence level, from “Do No Harm” to “Very High."
2. **Small Satellite Mission Lessons Learned and Best Practices**
   - Knowledge that focuses primarily Small Sat mission success/confidence, not satellite missions in general.
     - E.g., systems and processes may be more agile, teams may be smaller, member competencies may be broader
3. **Resilient System/Mission Design**
   - Knowledge on how to design a mission that will be resilient to failure
     - SmallSats should make every effort to implement design practices that yield functional resiliency or robustness. Specifically, the “mission system” should be designed to achieve as many key performance objectives as possible in the presence of subsystem failures or anomalous behavior, with performance degrading gracefully.

# Volunteers

- Section Lead: Mike Johnson
- Support
  - Robbie Robertson

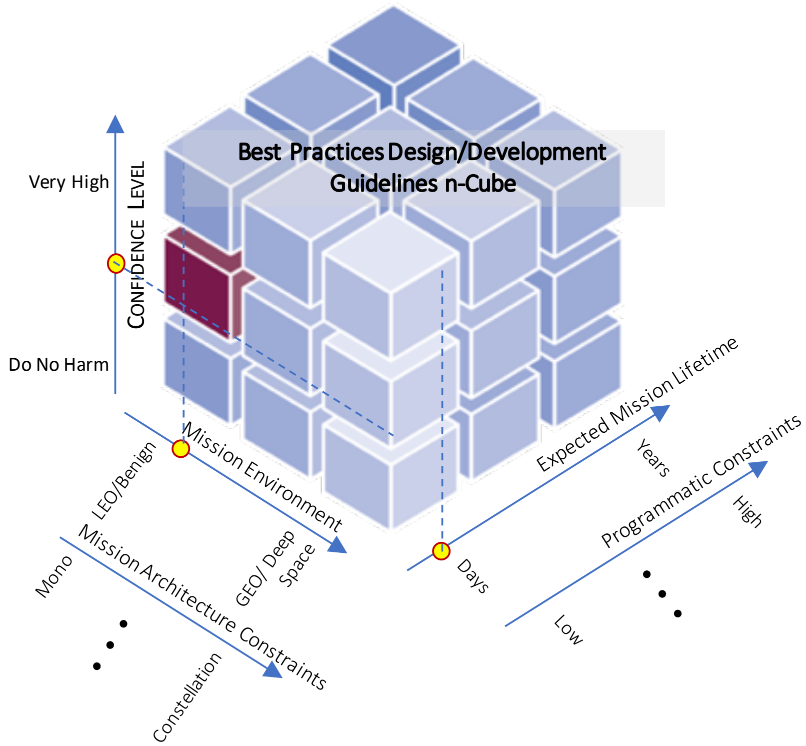
# Status, Needs, Further Discussion

1. **Mission Confidence Levels**
   - Question- What levels?  How many?
   - For example:
     1. Very High- failure would have extreme consequences to public safety or high priority national science objectives
     2. High- A high priority mission- Loss would compromise critical objective
     3. Moderate- Loss would result in delay of mission objectives
     4. Low- Cost/schedule are equal or greater considerations compared to mission success
     5. Do No Harm- A best effort mission



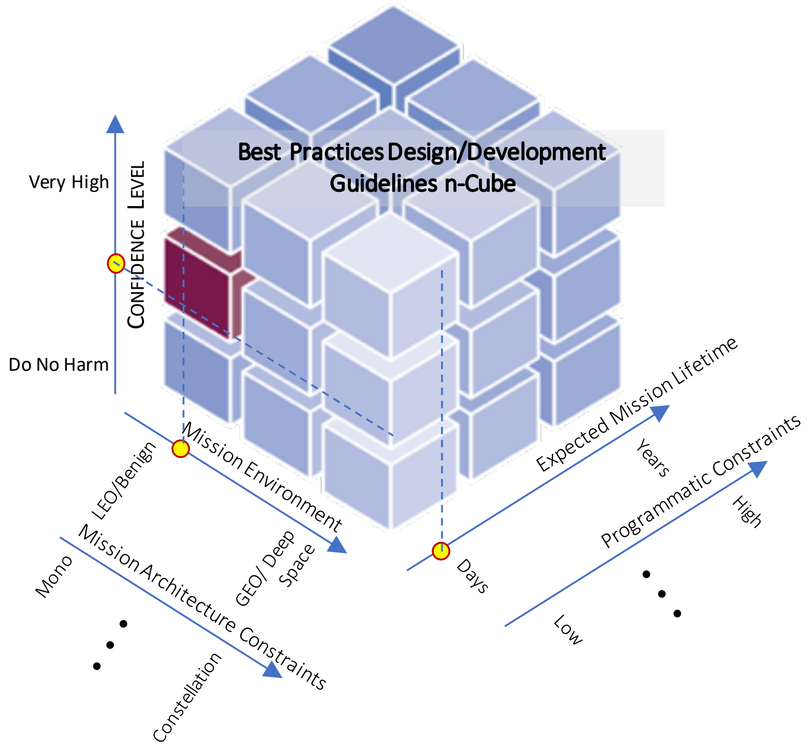
# Status, Needs, Further Discussion

2. **Small Satellite Mission Lessons Learned and Best Practices**
    - Capturing knowledge particularly relevant to SmallSats
    - Your input is invited and valuable



# Status, Needs, Further Discussion

3. **Resilient System/Mission Design**
   - Going beyond “system engineering” to “engineering the system”
   - Your input is invited and valuable



# Section 2: Expected Mission Lifetime

- This section looks a time driven effects across various trades. Categorize in three bins: <6 months, 6 months - 3 years, and >3 years.

1. **Space Environment**
   - Time driven effects on the space system due to the space environment, e.g. Radiation, Atomic Oxygen, Solar Wind, Micro-meteorites etc.)
     - GNC System
     - EPS system
     - Mechanisms
     - Compute/Memory
     - General Part Derating
2. **Thermal Trades**
   - Time driven effects on the thermal system and space system due to thermal degradation,
     - Effect of Thermal cycles on mechanisms and connectors
     - Radiator performance
3. **Power Trades**
   - Discussion of how power requirements change as a function of time on orbit.
4. **Guidance, Navigation, & Control Trades**
   - Orbital Trades vs. GNC needs
   - De-orbit system reliability
   - Maximizing low altitude mission capability
5. **Design, Test, & Analysis Trades**
   - Sub-system Design, Parts Selection, and Software Trades as a function of expected mission duration.
   - Part Selection – SRL/IRL, COTs, heritage, etc.
   - Analysis Rigor
   - Testing Rigor

# Volunteers

- Section Lead: Lee Jasper
- Support
  - Linda Fuhrman
  - Jim Lohman

# Status, Needs, Further Discussion

- Knowledge capture
- Team augmentation

# Section 3: Space Environment/Orbital Constraints

- System trades driven by constraints derived from changes in orbit/altitude (LEO, MEO, GEO, Inter-Planetary)

1. **Space Environment**
   - trades driven by different altitudes (Radiation, Atomic Oxygen, Solar Wind, Micro-meteorites etc.)
     - GNC System
     - EPS system
     - Mechanisms
     - Compute/Memory Considerations
     - General Part Selection & Derating
2. **Thermal Trades**
   - Active vs. Passive needs
   - Surfaces, coating, and materials (also include charging effects, etc.)
3. **Power Trades**
   - Trades in EPS system due to different orbital regimes
4. **Communication Trades**
   - Includes TT&C and Data downlinks (direct, relay, crosslinks)
     - Allocating Margin
     - Interference Concerns
5. **Guidance, Navigation, & Control Trades**
   - Propulsion Trades
6. **Test & Analysis Trades**
7. **Launch (environment, integration)**
   - General do no harm practices
     - Canisterized
     - ESPA Payload
   - Integration
     - Launch Prep
     - Shipping
     - Vibe/Launch Loads

# Volunteers

- Section Lead: Kevin Klein
- Support
  - Jim Lohman
  - Doug Sheldon

# Status, Needs, Further Discussion

- **Status:**
  - collecting input info and documents
  - most helpful example so far is ISO 19683 spec for "Space systems – Design qualification and acceptance tests of small spacecraft and units"

**Needs :**

- expertise and volunteers
- documents and references, particularly those that help explain
  - technical tradeoffs involved in designing for different orbits
  - tradeoffs between risk reduction and cost reduction (mission constrained vs. resource constrained)
  - holistic approaches to overall cost of design (e.g. saving a few $ on a component leading to $$$$ in test cost)

# Section 4: Programmatic Constraints

- Programmatic constraints associated with a small satellite mission development program will inform execution of one or more phases of the program.
- This will impact the mission system and have potential to impact mission confidence.

1. **Team Personnel Acumen and Experience**
   - System development trades and knowledge resources derived from team experience
     - Internal Team Assessments
     - Design/Development Process to offset knowledge gaps
     - Obtaining external knowledge and experience resources
2. **Available Resources [for end-to-end mission delivery]**
   - Guidelines and system trades to conduct long term resource planning
     - Documentation Needs
     - Team Continuity Expectations and Planning
     - Transition
3. **Development/Test Facilities**
   - Facility trades based on resource constraints and mission needs
     - Facility identification and needs
     - Test Equipment
4. **Mission Design/ Development Time/Schedule**
   - Deriving mission schedule through resource constraint trades
     - Schedule
     - People phasing
     - Money
     - Facilities
5. **Technology/Component Relevant History and Heritage**
   - Outline key trades in design, development, and test against component maturity
     - Flight history and flight anomalies tracking
     - Configuration Management of previous
     - Process repeatability of the supplier
6. **Licensing & Regulations**
   - Provides a quick resource to ensure major licensing and policy's have been addressed
   - Frequency
   - Flight Safety
   - Remote Sensing
   - NASA Compliance
   - DoD Compliance

# Volunteers

- Section Lead: Dan Perry
- Support
  - Ken Hyatt

# Status, Needs, Further Discussion

- **Status:**
  - Resource Mapping:
    - Combining and mapping resources from previous TIMs to the outline
    - Researching and mapping open source references and resources to the SharePoint site
  - Outline Refinement:
    - Validating the sub-elements in the outline map appropriately and are meeting the intent of the effort
- **Needs:**
  - Data.
  - Ideas on how to best reference and sort the different tools and approach non-open source resources
- **Further Discussion:**
  - What is missing that should be included in the end product?

# Section 5: Mission Architecture Constraints

- This section looks at impacts and considerations for different mission architectures. Mission architectures can be a single spacecraft, swarm, or a large constellation.

1. **Design, Test, and Analysis Trades**
   - Risk posture and program maturity
   - Team Experience
   - Security/Safety (e.g. cyber, encryption)
   - Assembly line vs one-off build
2. **Launch Availability Trades**
   - Dedicated vs rideshare launch
   - Timeliness and reliability of launch (launch when and where you need it - what are those trades and impacts to mission confidence)
   - Build-up and sustainment of mission (for swarms and constellations)
3. **Ground Systems & Mission Ops Trades**
   - Global network vs single station
   - Lights out operations vs fully manned (autonomy and automation)
   - On-orbit asset availability (operation tempo)
   - Security/Safety (e.g. cyber, encryption)
   - Downlink/uplink via crosslinks, direct space to ground, or combination
4. **Robustness Trades**
   - Trades that highlight the differences of a large constellation from a single spacecraft
5. **Manufacturing Trades**
   - Reuse Parts - multiuse vs single use down to the component level
   - Business decisions trades (monetary trade)
   - Assembly line vs one-off build

# Volunteers

- Section Lead: Catherine Venturini
- Support
  - Linda Fuhrman
  - Tony Diventi

# Status, Needs, Further Discussion

- **Status:**
  - Reviewing/researching current literature and references

- **Needs**
  - Identify missions that have looks at the trades between single and many spacecraft – gather lessons learned
  - Need industry volunteer to help with manufacturing trades

# Final Thoughts…

Your thoughts?

Please let us know if you’re willing to contribute.

# Approach to sharing

- Assume a broad set of potential users from acquisition, development, launch, and mission ops and can be from industry, academia, or government
- These users can be a novice to advanced user depending on their experience and background
- Web-based interactive tool
  - Advanced user mode
    - Body of knowledge accessible via search
  - Novice user mode
    - “Turbo Tax” or flowchart like
    - User is guided by a series of questions