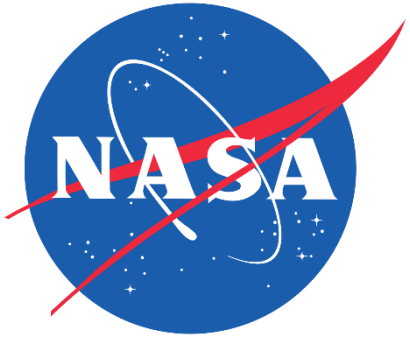
Spacecraft Anomalies and Failures "SCAF" Workshop 2017

Mr. Alec Engell on behalf of
Dr. Darren McKnight (IAI)

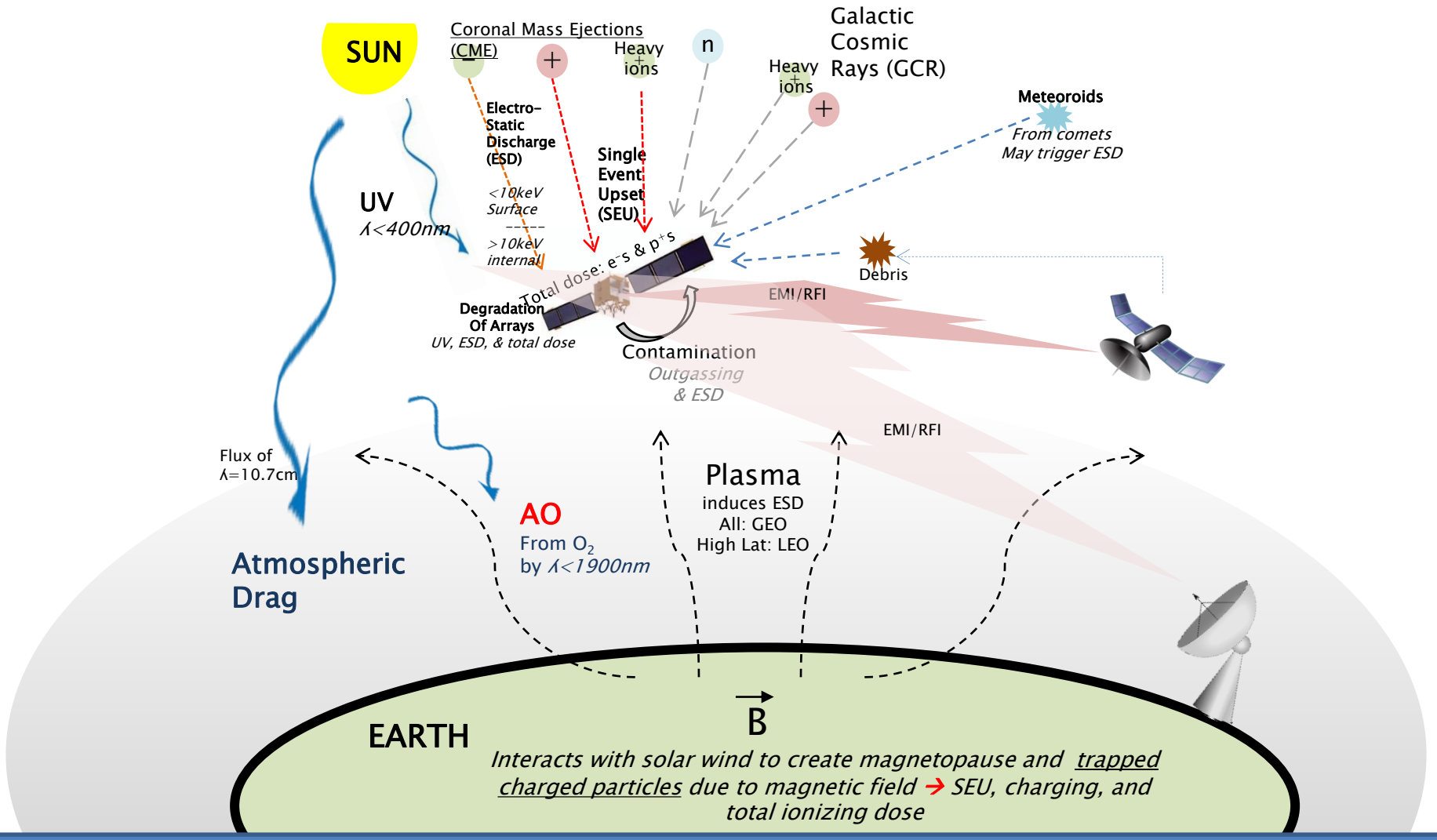


Integrity Applications Inc.

SCAF Operational Motivation

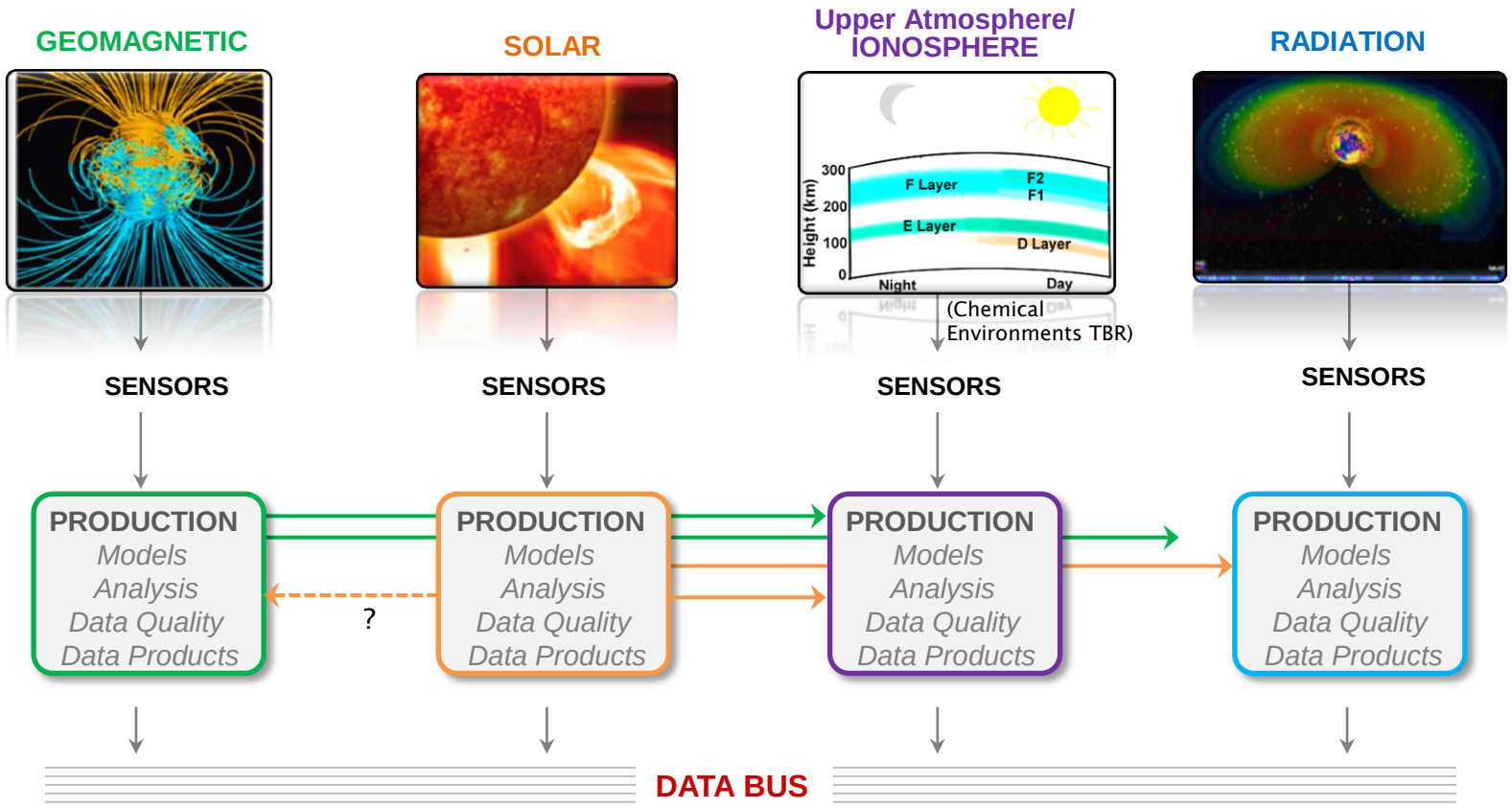
- Presidential Policy Directive
  - National Space Policy, 2010
    - "Improve, develop, and demonstrate, in cooperation with relevant departments and agencies and commercial and foreign entities, the ability to rapidly detect, warn, characterize, and attribute natural and man-made disturbances to space systems of US interest."

- **Disturbances on spacecraft** – understand physics
- **Cooperative across multiple agencies** – who to talk to
- **ID triggers and effects** – what questions to ask



Complex interactions of chemistry, radiation, and particles

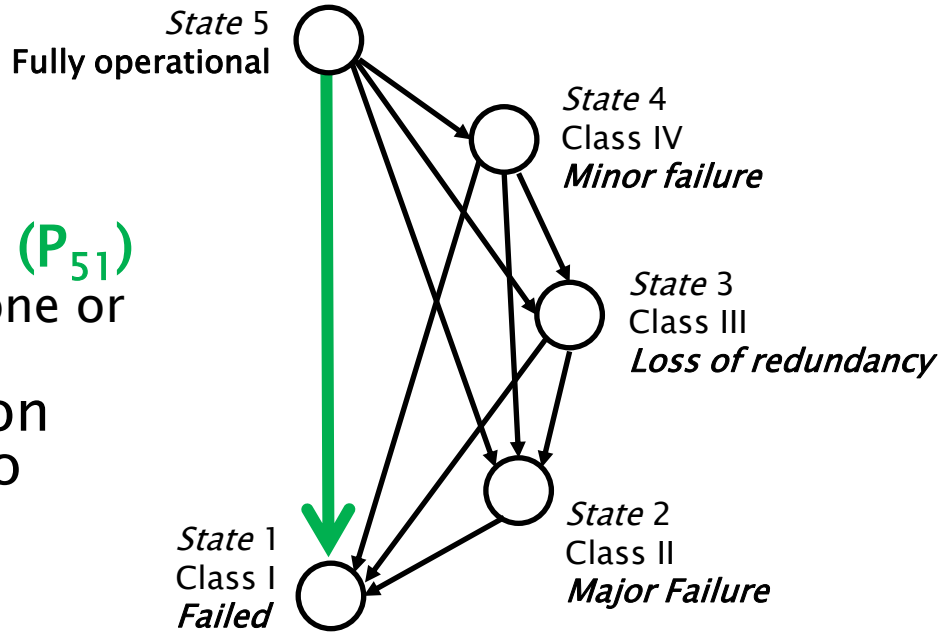
Space Environments



Courtesy of Dr. Mike Regan

Take Nothing at Face Value

- **Unitary failures are rare (P_{51})**
  - May transition through one or more degrees of failure
- Several ways to transition from fully operational to failed:



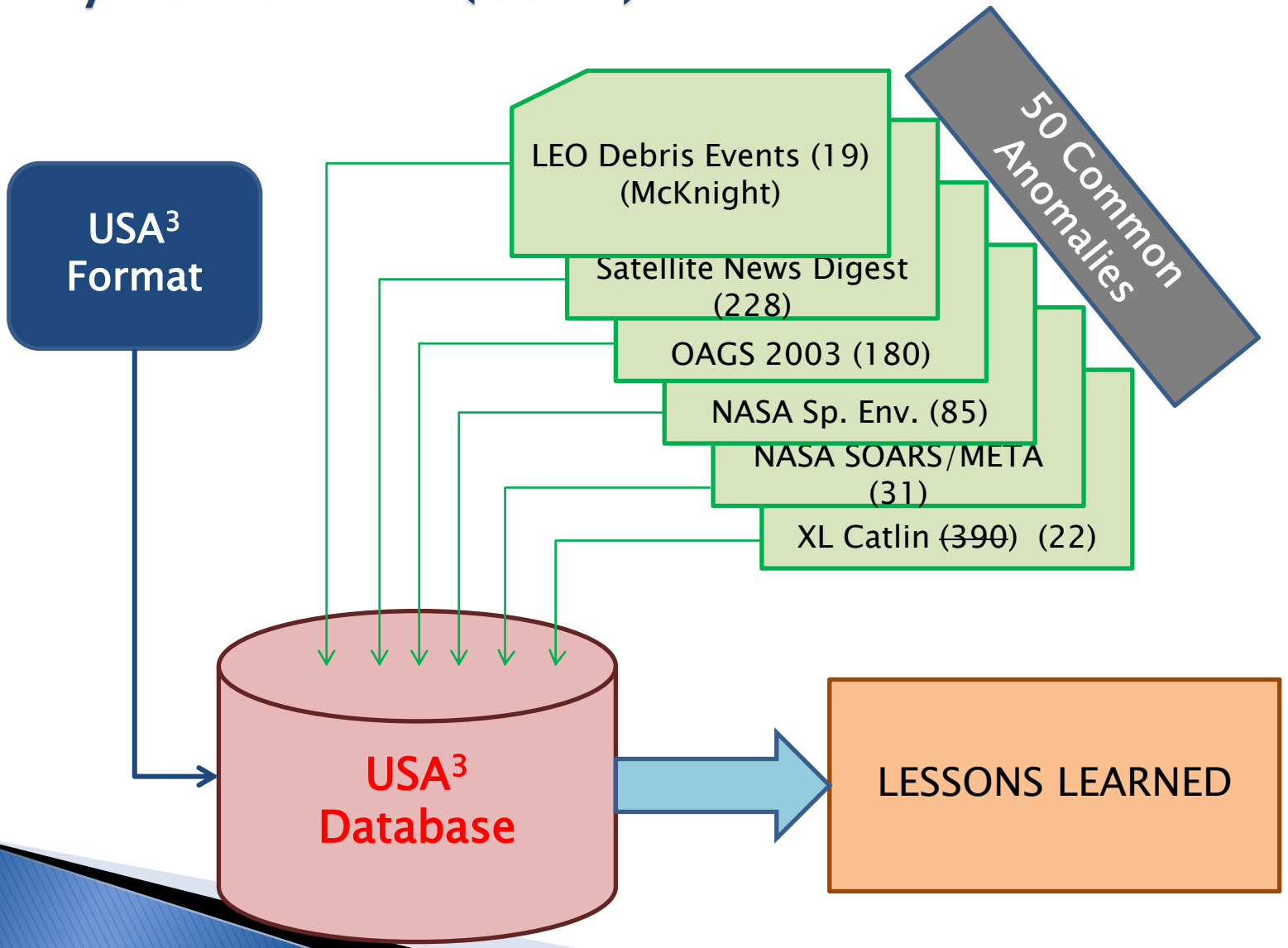
$$P_{51}' = P_{51} + [P_{41}/P_{54} + P_{31}/P_{53} + P_{21}/P_{52} + P_{52}/P_{42}/P_{54}]$$

Castet, Jean-Francois and Saleh, Joseph H., "Beyond Reliability, Multi-State Failure Analysis of Satellite Subsystems: A Statistical Approach," Reliab Eng Syst Safety (2009), doi:10.1016/j.ress.2009.11.001

SCAF Workshop 2017

- 100 participants at the 5th annual workshop
  - Government and Industry roughly equally split
  - 20 presentations
- Two days in Chantilly, VA
  - first: unclassified second: classified
- Examines how:
  - People, processes, and technologies may be leveraged to
  - Identify, characterize, and attribute spacecraft anomalies as being caused by manmade or natural effects
- Focus on attribution and conclude:
  - Lessons learned not enough; must transform lessons learned into the new context (architecture?) to exploit previous benefits

Universal Satellite Anomalies Analysis Advisor (USA³):

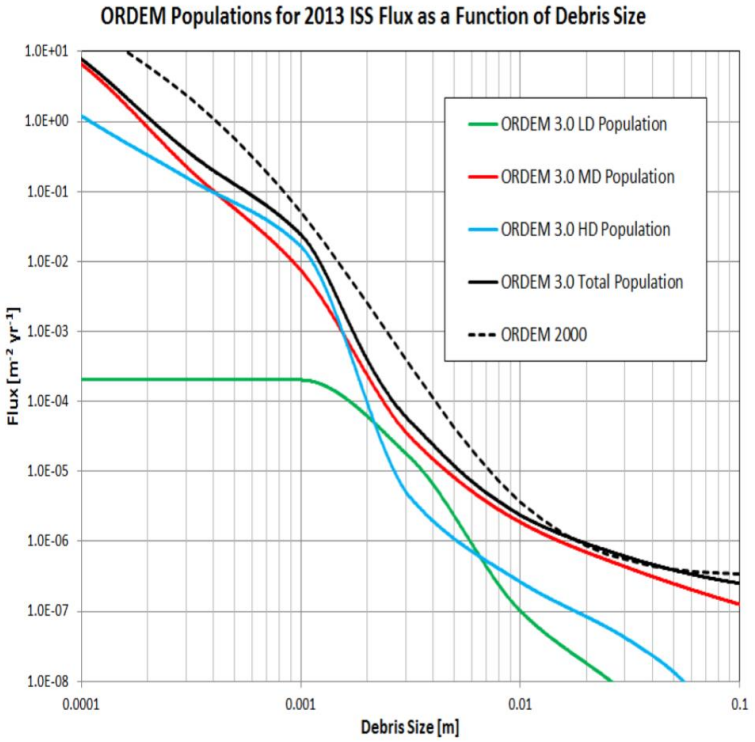


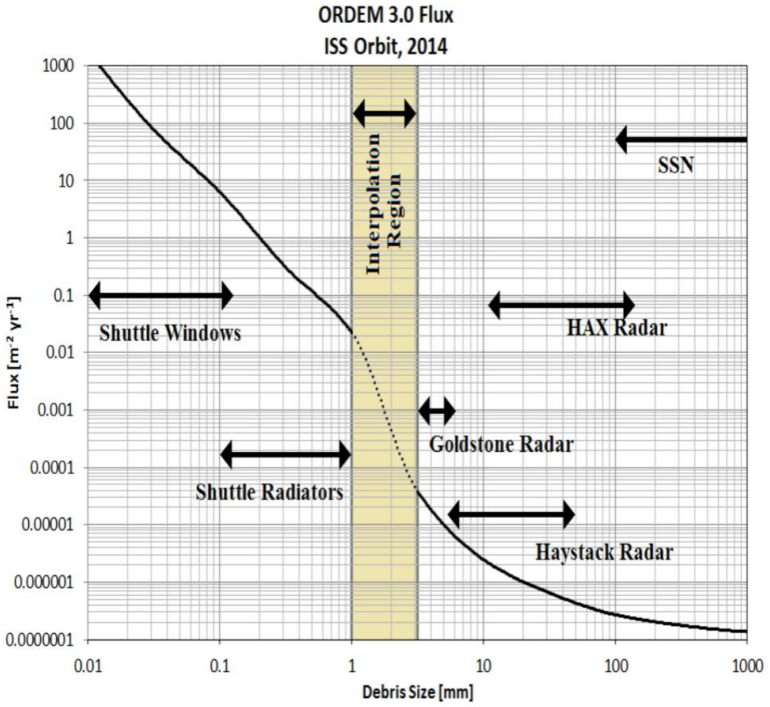
USA^3 Lessons Learned

- Simple data inconsistency is a big issue
  - Different launch dates
  - Different names
    - Palapa 1C <-> HGS3 <-> Anatolia <-> PaK
- Poor traceability of more complicated data
  - mission effects – system status – subsystem status – component status
- There are information sharing limitations
  - Open Source – authoritative source?
  - Commercial – proprietary restrictions
  - Military/IC – security limitations
- Indeed, symptoms not specific to lowest possible hardware level and definitely not time-sequenced
  - Observables ≠ symptoms

Modeling Orbital Debris Flux to Support Anomaly Attribution

- NASA's Orbital Debris Engineering Model (ORDEM 3.0)
- Left panel shows typical flux curves for the International Space Station (i.e., 400km)
  - LD – phenolics; MD – aluminum; HD – copper/steel
- Right panel shows the sources used to develop the ORDEM model = returned samples + observations + engineering judgement





Modeling Debris Shape to Support Anomaly Attribution

- Major area of study right now is in determining the shape of orbital debris as this characteristic will greatly affect the lethality of debris
- March 2018 deployment of the new Debris Resistive Acoustic Grid Orbital Navy-NASA Sensor called the Space Debris Sensor (SDS)
  - Will provide a valuable sensor for improving ORDEM by garnering *in situ* measurements of
    - debris size
    - energy
    - velocity
    - mass
- SDS will be mounted on the leading edge of the ISS and is slated to provide real-time data for the next three years.

Key Observations 1/2

- Draft "how to deal with satellite anomalies" white paper as best practices
  - focus on time-sequenced symptoms to contribute to anomaly attribution
  - DRAFT AVAILABLE from *dmcknight@integrity-apps.com*
- 2016 SCAF resulted in anomaly attribution for NASA spacecraft (capacitor failure)
- Despite classification issues/concerns – SCAF should bridge the gap for commercial space operators that are typically analyzed and responded to by DoD/IC

Key Observations 2/2

- Attribution process:
  - People → Processes → People
    - People: SMEs – hardware, software, design, parts heritage, etc.
    - Processes: Root cause determinations tools and documentation & rigor of the investigation (need processes expert!)
    - People: Oversight, participation, and interrogation by "seniors to provide top-cover for the dissemination of data" – leadership and management skills to ensure complete, comprehensive and correct
- Spacecraft have sensors and components that capture relevant data that have not been fully leveraged in the past
- Keynote Listener very productive – maximized workshop dialogue

2018 Agenda Forming…

- Machine learning applied to anomaly attribution
- SDA to address how their services can benefit anomaly attribution
- NASA NESC to report on the difficulty in tracing impact on spacecraft to environmental models
- 50-years of satellite anomaly resolution efforts (discussion)
- Cyber threat on spacecraft operations

Thank you!

- *Darren Mcknight*
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