National Aeronautics and Space Administration

Breakup Event Attribution & Consequences

M. Matney

With special thanks to P. Anz-Meador

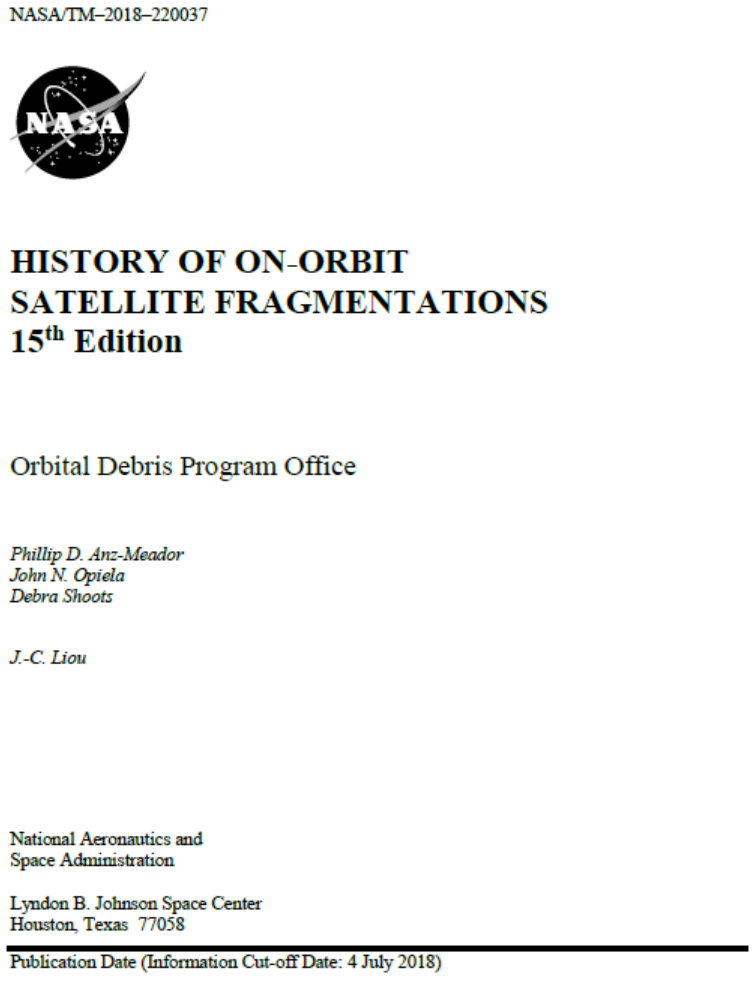
NASA Orbital Debris Program Office

SCAF Workshop
December 8, 2020

NASA Orbital Debris Program Office
History of On-Orbit Satellite Fragmentations

- **The NASA Orbital Debris Program Office (ODPO) publishes the History of On-Orbit Satellite Fragmentations* to chronical satellite breakups, anomalous events, and aerodynamic breakups**
  - Originally developed by Teledyne Brown Engineering of Colorado Springs under contract to ODPO
  - 15th Ed. describes events through 4 July 2018
  - 16th Ed. in preparation
- **Associated products include tables of events ordered by international designator (launch sequence) and event date**
- **Includes breakup event attribution**

*Available for free download from the NASA Orbital Debris website



NASA/TM–2018–220037

HISTORY OF ON-ORBIT SATELLITE FRAGMENTATIONS
15th Edition

Orbital Debris Program Office

Phillip D. Anz-Meador
John N. Opiela
Debra Shoots

J.-C. Liou

National Aeronautics and Space Administration

Lyndon B. Johnson Space Center
Houston, Texas 77058

Publication Date (Information Cut-off Date: 4 July 2018)

Breakup Event Attribution Spectrum

- **A spectrum is used to describe the information content and associated veracity or likelihood of the assessment**

Original Equipment Manufacturer (OEM)/Owner-Operator report:

Delta, Delta II second stages: analysis of residual fuel/oxidizer

Direct Observation:

ASATs, Cosmos 2031 class end mission by self destruct

Inference

Prior history: (same system or vehicle)

Able Star => Delta => Delta II common bulkheads

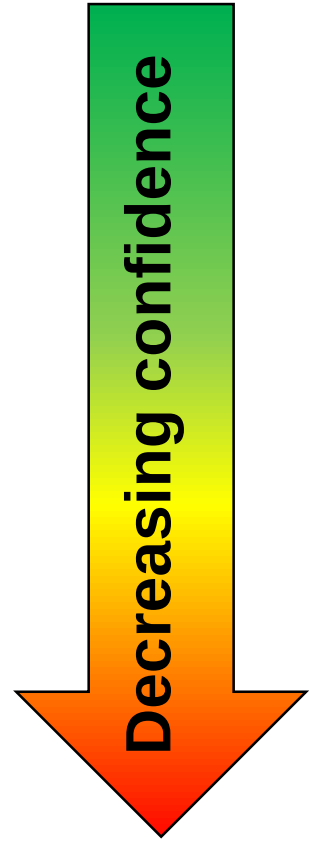
Similitude: (different vehicle, like systems)

Residual propellants, including hypergolics + common bulkheads

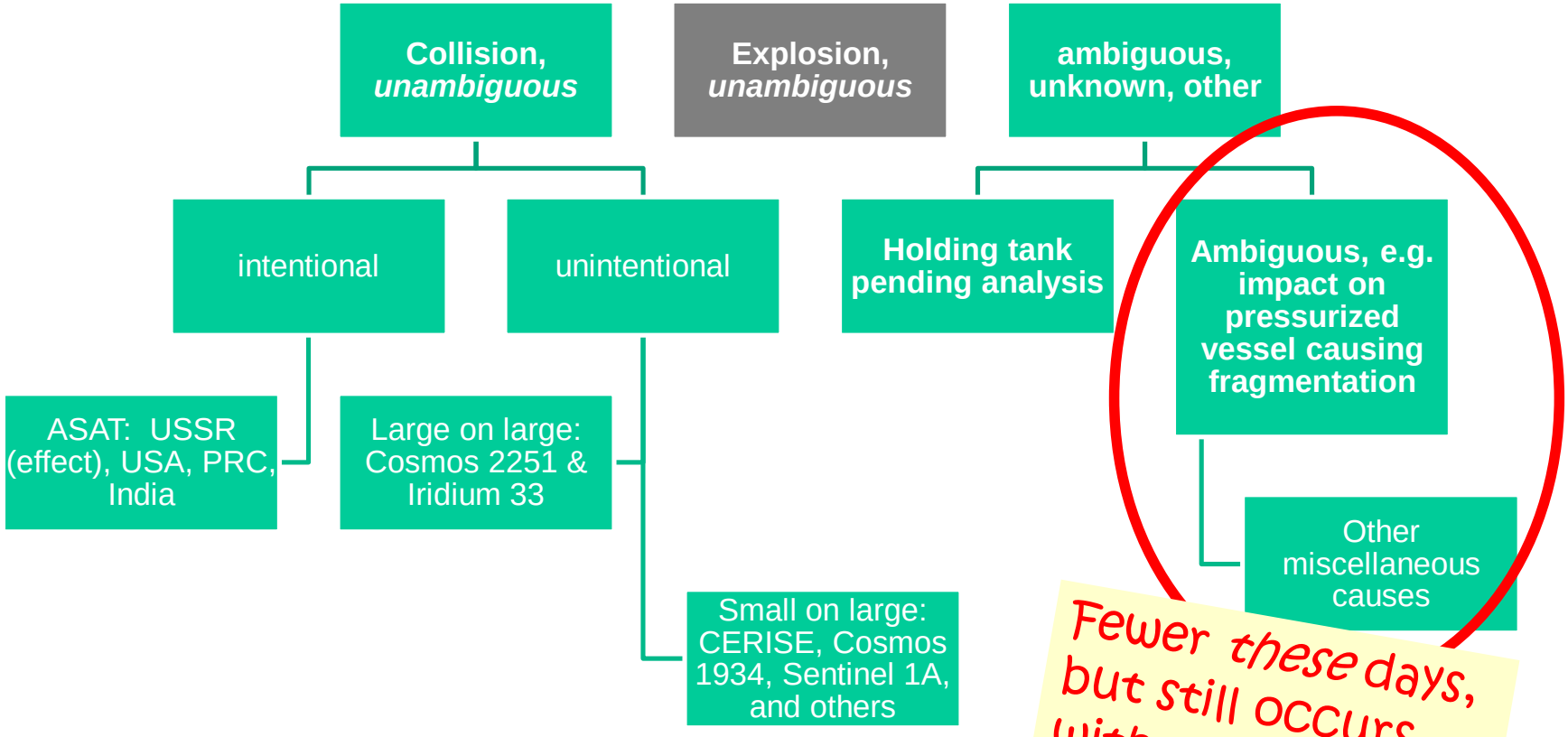
Circumstantial:

CZ-3 third stage breakups likely explosions because collisions deemed statistically unlikely in GEO Transfer orbits (GTO)

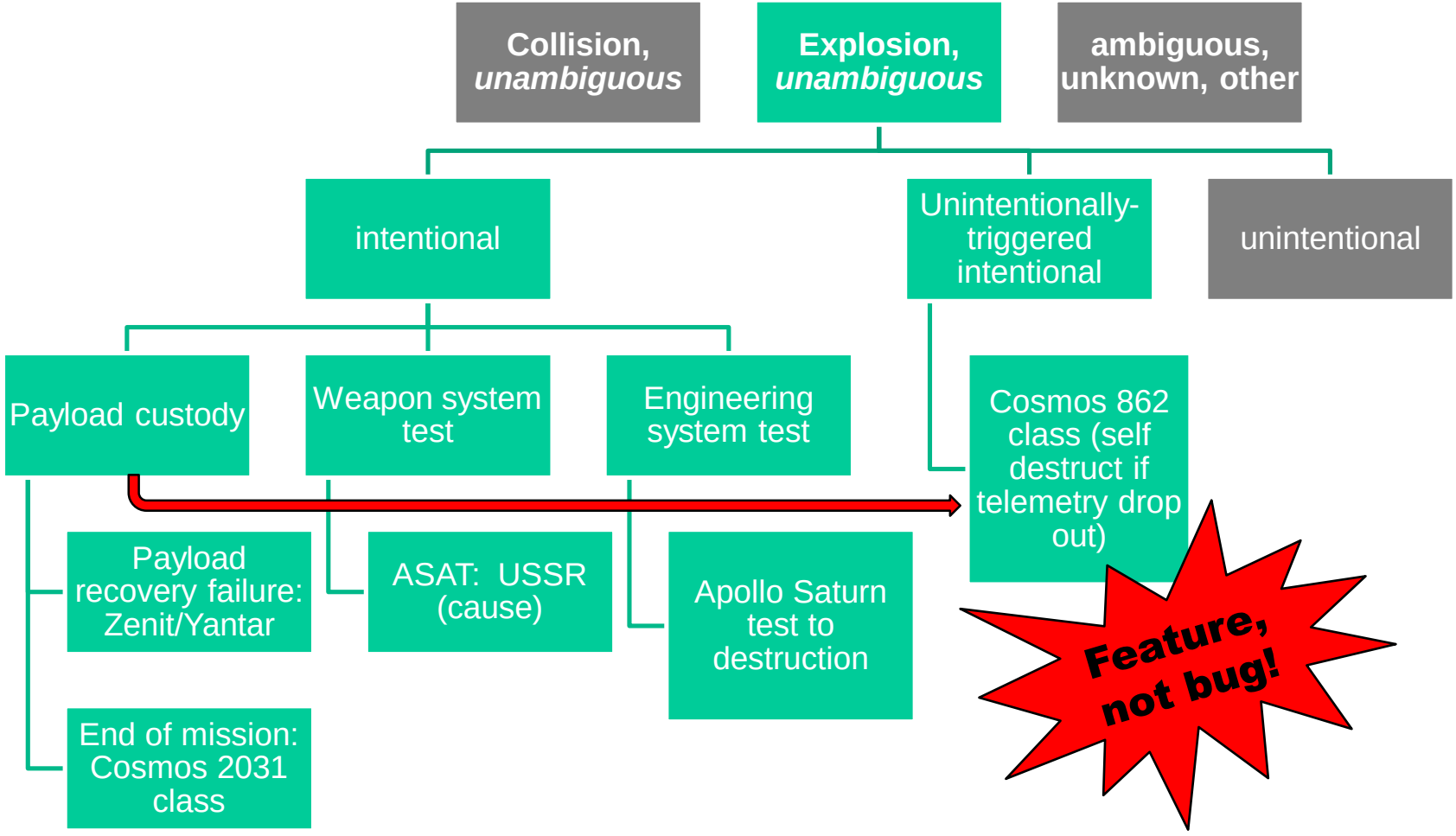
Unknown: … lack of analyst time to "no available information"



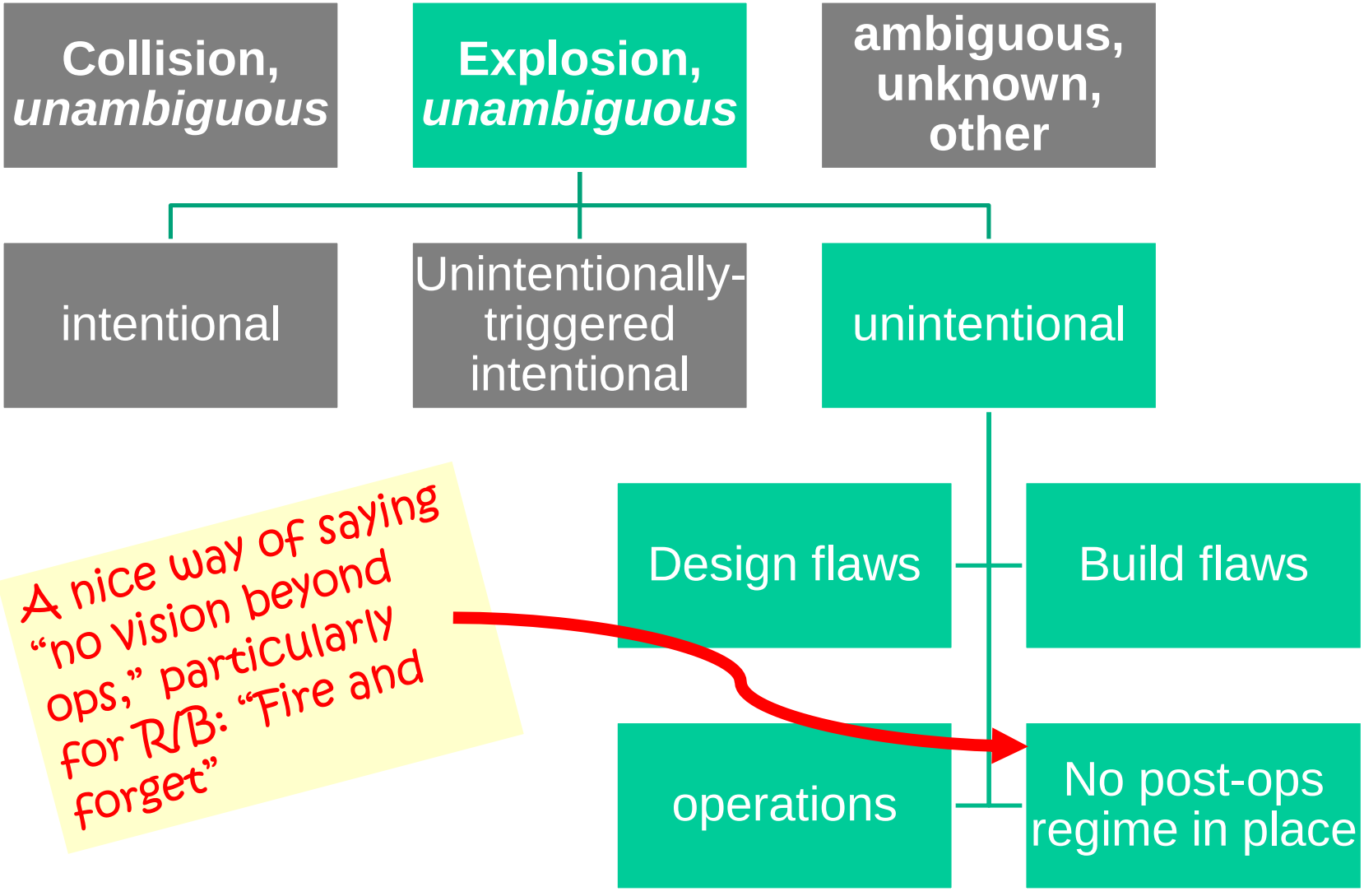
Breakup Event Attribution by Event Type I



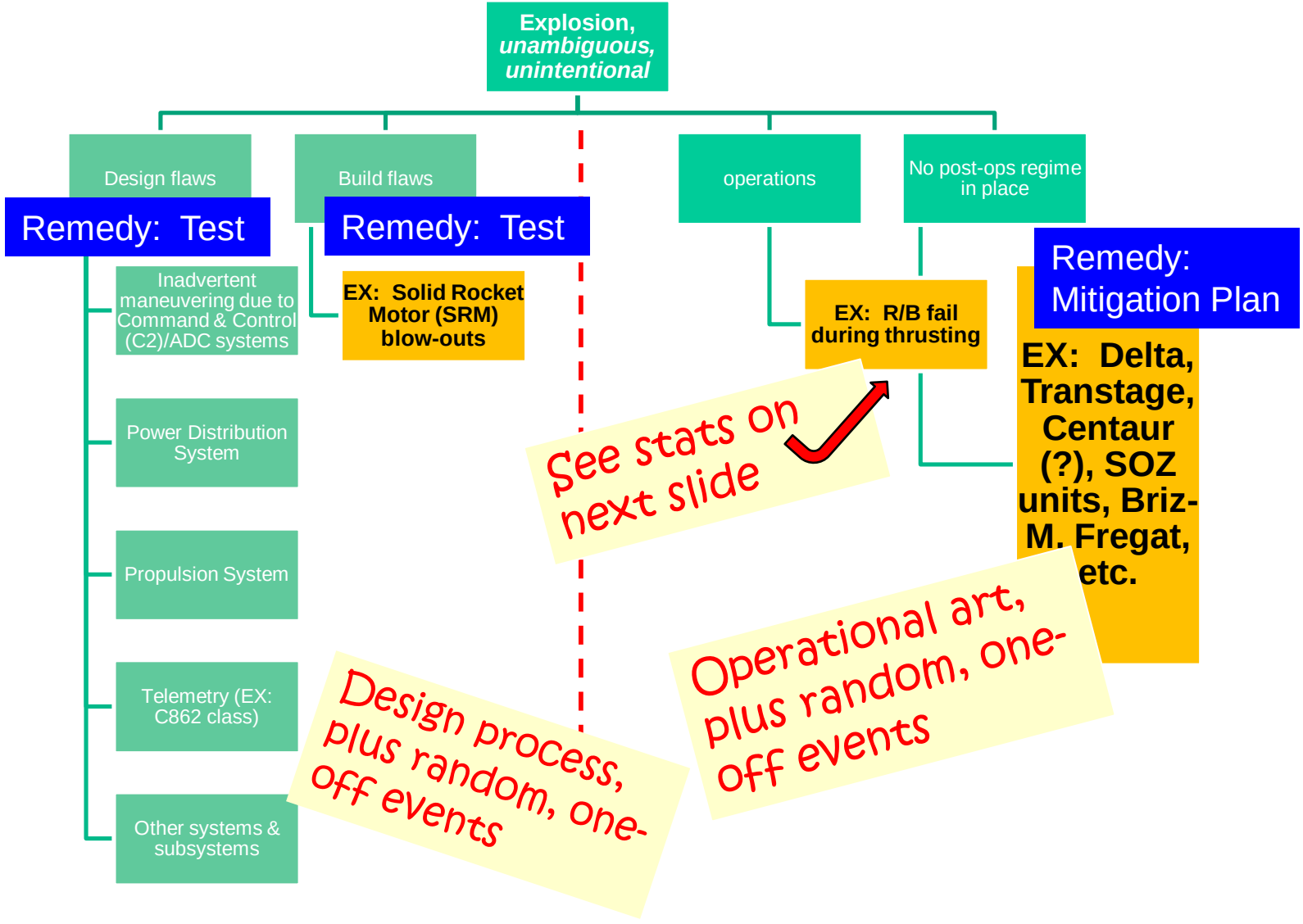
Breakup Event Attribution by Event Type II



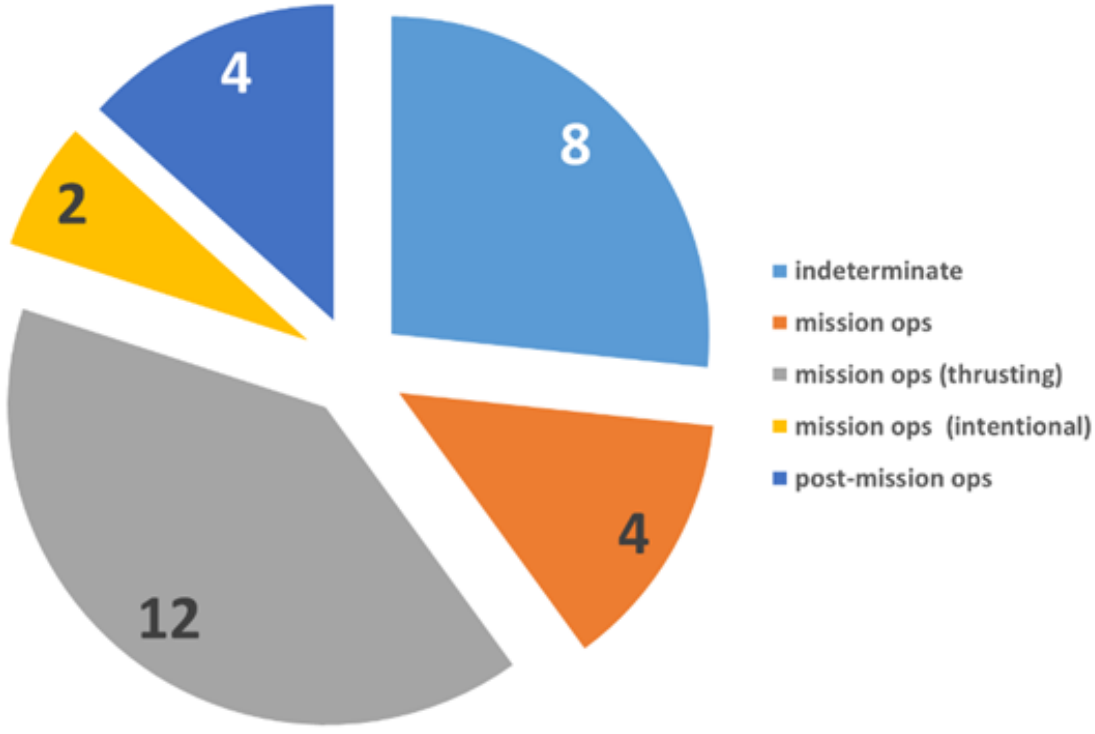
Breakup Event Attribution by Event Type III



Breakup Event Attribution by Event Type IV



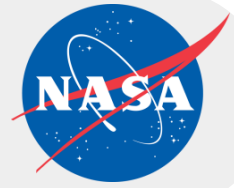
Early-time R/B Failure Statistics



Mission operations can include thrusting or coasting prior to payload separation and avoidance or stage passivation activities. In two cases the event was intentional and are so noted. The other two categories are post-mission operations and indeterminate, in which the exact timing of the event is not possible.

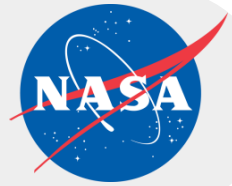
- Statistics generated from 15th Ed. event tables
- Seven days or less between launch and event
- 30 events
  - 26 on or within 1 day of launch day
  - 3 are 2-3 days after launch (cataloging difficulties in deep space)
  - 1 > 3 days (Shuttle deployed stage)
- "Indeterminate" category likely occurred during thrusting or shortly after

Propulsion Case Studies: OEM Reporting



- Delta IV second stage debris production events; 2006-050B and 2007-054B
  - Production of debris did not affect stage performance or successful payload delivery + post-ops
  - Joint OEM-US Government investigation, formal root cause analysis conducted successfully
  - No subsequent events
- Falcon 9 v. 1.1 second stage debris production event; 2013-055B
  - Engine restart for deorbit burn failed
  - OEM: “we got this”; little substantive interaction with ODPO
  - No subsequent events
- Pegasus Hydrazine Auxiliary Propulsion System (HAPS) fourth stage event; 1994-029B
  - Premature shutdown => likely residual propellant
  - Only 97 kg dry mass, produced > 700 cataloged pieces
  - Joint OEM-US Government investigation
  - Launch license denied for follow-on missions until mitigation plan developed and implemented
  - No subsequent events

Breakup Event Attribution: Consequences



- Notable design or implementation flaws
  - Power distribution system
    - Defense Meteorological Satellite Program (DMSP, Block 5D2)
    - Nine members of this Block
    - Three have fragmented during or post-ops
    - All members of class may fragment in sun-synchronous orbits
  - Telemetry system
    - Cosmos 862 class
    - This class of events named after first member to have been observed to fragment
    - All members of this class have likely fragmented prior to introduction of design modification, but Molniya-type elliptical orbit can render observations and cataloging difficult
- No post-ops regime in place
  - SOZ units: ullage motors for SL-12 Proton fourth stages
    - 52nd unit fragmented in December 2019
    - 32 units remain on orbit
    - No reason to doubt that the remainder will fragment over time

Old, derelict objects may yet explode; all objects provide area and mass reservoirs for collision processes

Conclusions

- **Data-driven models require an accurate understanding of the nature and causes of debris-producing events and how the debris clouds evolve over time**
  - Models include short-term risk assessment to long-term assessment of mitigation methodologies and effectiveness
- **Accurate event attribution can be challenging, and can display varying levels of confidence**
- **Explosions have been a major contributor to historical debris production**
  - Spacecraft (unintentional fragmentation): design flaws
  - R/B: operations + no post-ops regime (prior to introduction of mitigation standard practices
- **Mitigation efforts by the international community appears to be paying dividends**
  - However, collisions between uncontrollable objects likely will dominate the long-term evolution of the environment
  - About the time we fix one system, a new one with new (or repeat of old) problems is deployed