Space Debris Mitigation Health Monitoring Compliance - Full Steam Ahead

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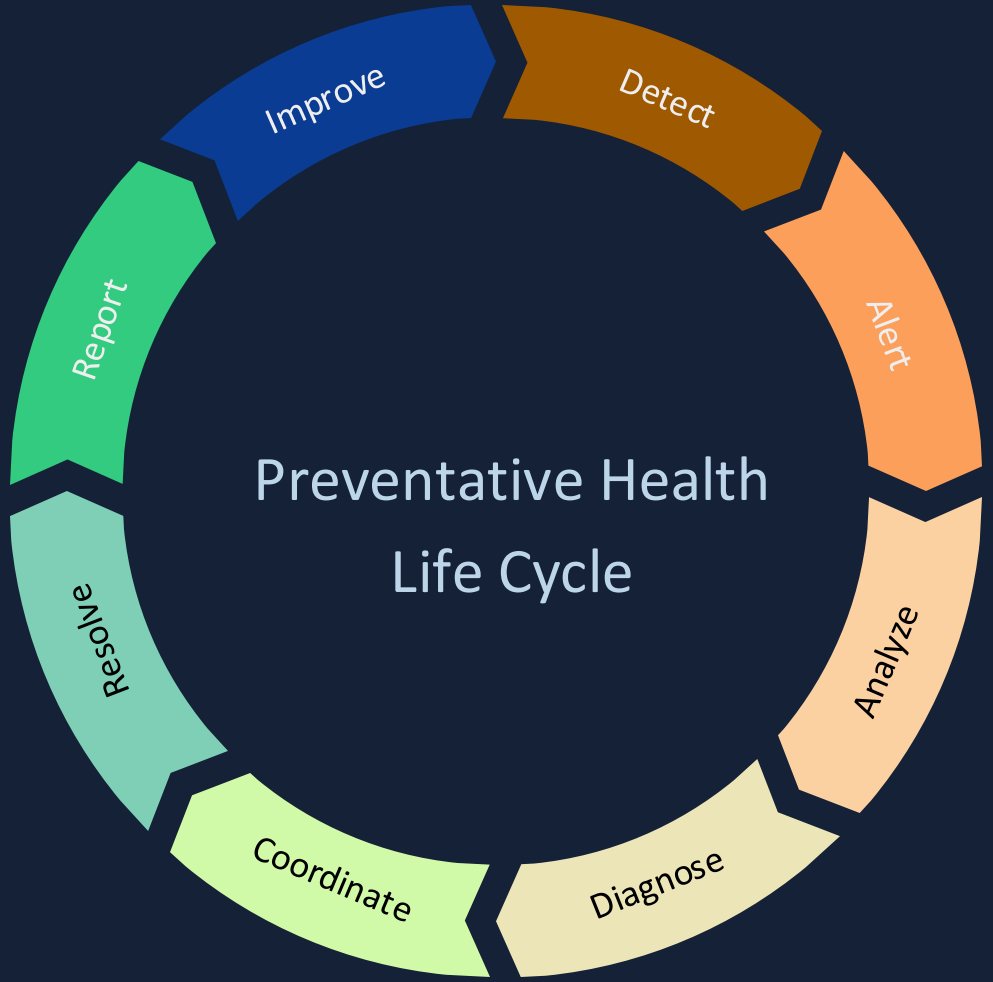
Intella

Health Monitoring

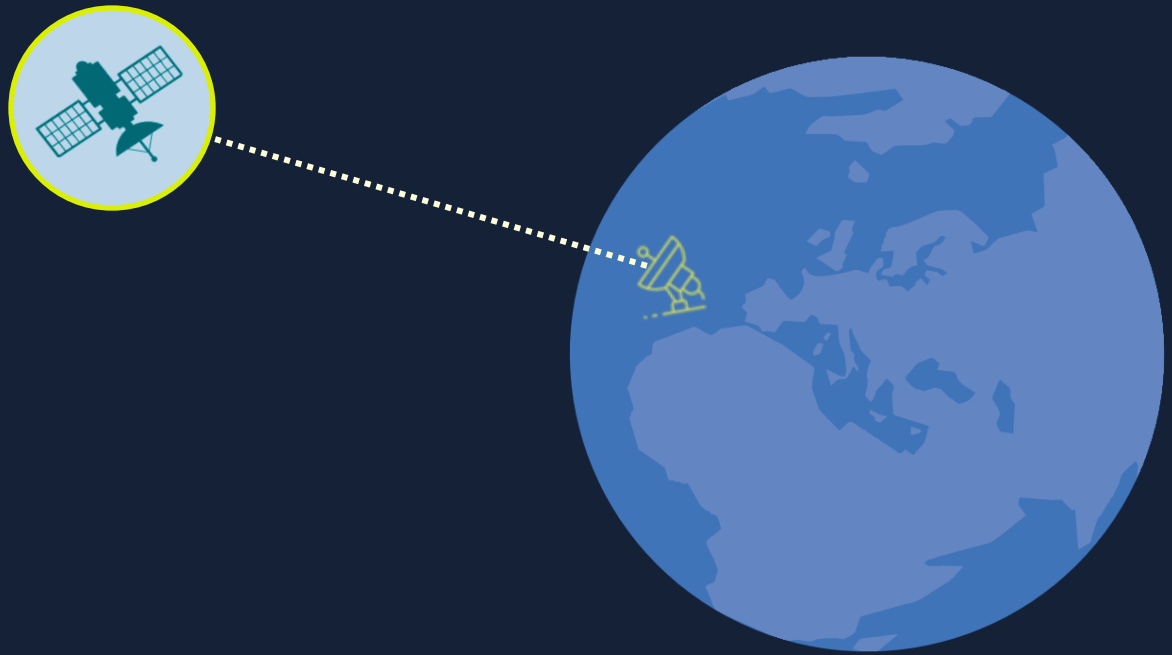
Satellite Health

Health Monitoring

Satellite Health



Scenario – A Not-So-Distant Future



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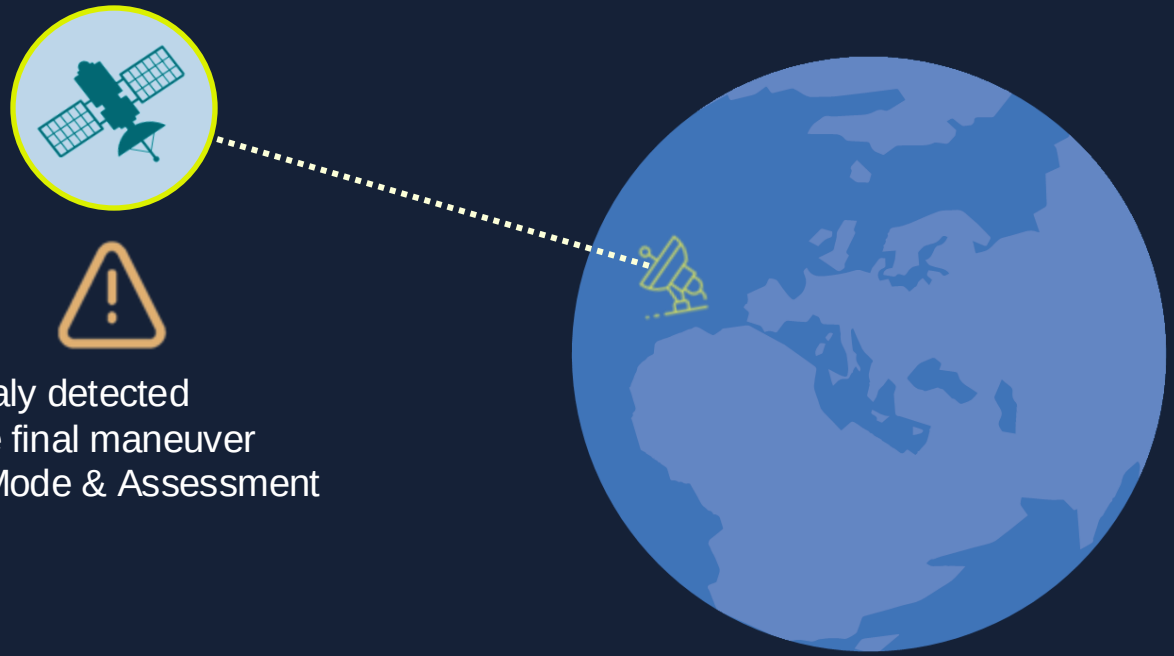

Anomaly detected
Before final maneuver
Safe Mode & Assessment

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Automated
Traffic
Notification

Conjunction
Probability
Assessed

Component Issue Documented
Prognostics Model Updated
Successful Disposal – Minimal Impact

Anomaly detected
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Design Cycle Closure & Data sharing

Health Montoring - Requirements

Spacecraft Health Monitoring

Failure Prognostics

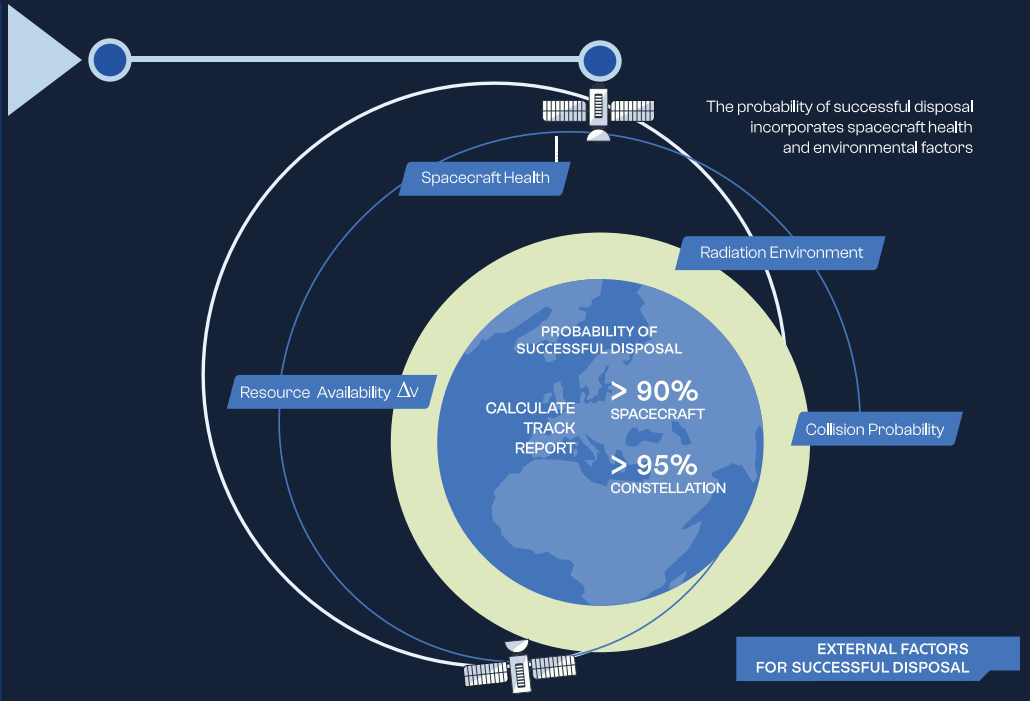
- Model-based
- Return of Experience
- Stochastic, model-basedl data trend
- Remaining Useful Life (RUL)

Diagnostics & Anomaly Mgmt

- In-flight data analysis
- Early anomaly detection, attribution, and mgmt
- Lessons learned (Anomaly – Failure)
- Future insight integration

Critical System & Component Monitoring

- Wear-out data tracing
- Failure in Time (FIT)



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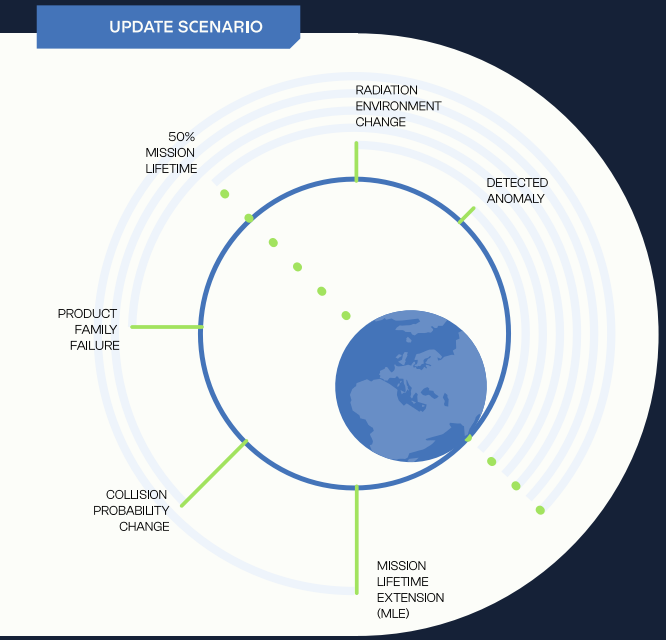
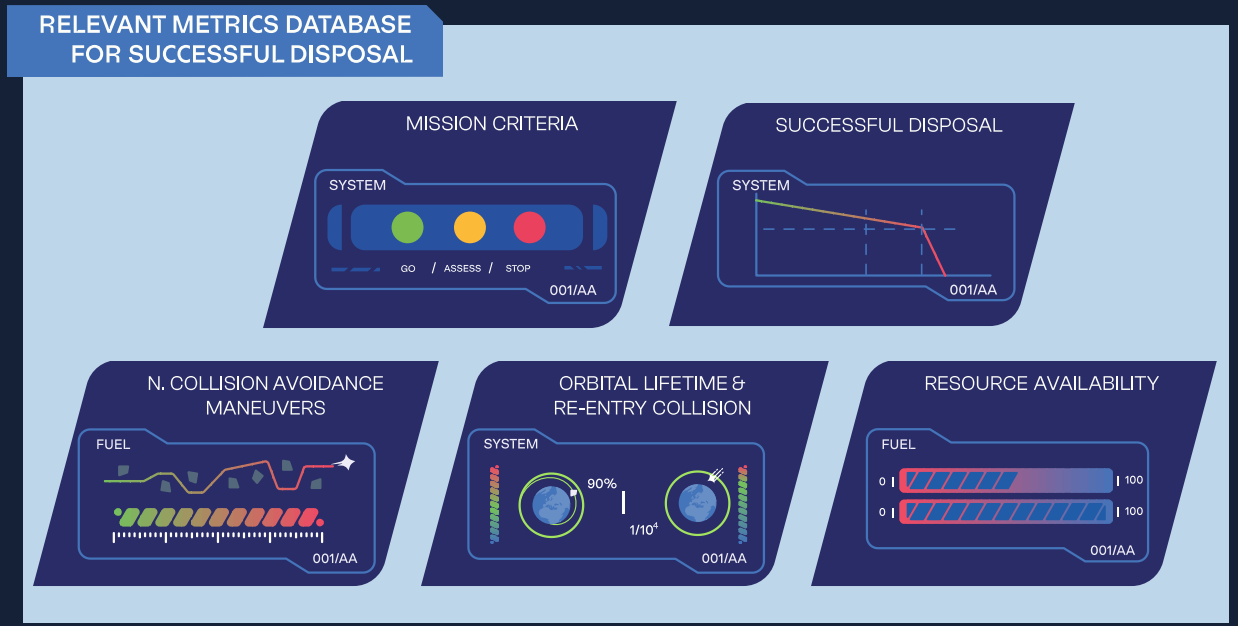




Detection, Diagnostics, and Prognostics

- Solutions are available
  - Ops teams can already benefit from monitoring
- Healthy development effort – Institutions & Industry
  - Technology and accessibility are maturing
- Institutional and Academic Resources:
  - RAMS Methodologies
  - Wear-out trends – latest models
  - Probability of Successful Disposal
  - Additional useful metrics

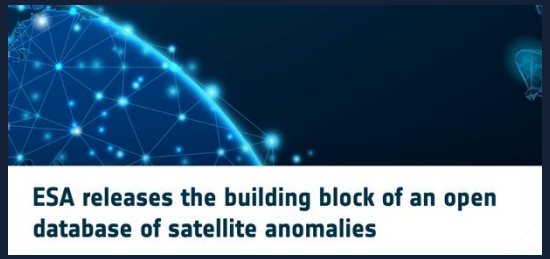
Mercury
Intelligent Anomaly Management

gifted_GENE

CASTEC

AI Validation Opportunities

- How do we evolve traditional Certification?
  - How can we have certified models and detection methods?
- Powerful unsupervised methods are available
  - Dynamic and provide benefits in time-sensitive scenarios
  - Anomaly characteristics not well-characterized
  - Statistical in nature
- Require Accepted Validation Approaches
  - Benchmarking
  - Common Datasets
  - Maintenance, growth, and anonymization approachs
  - Borrow from healthcare, cybersecurity, and pharma
- Unsupervised models + Human in the loop
  - Near-term synergy
- Matters of Perception – Demystifying Complexity



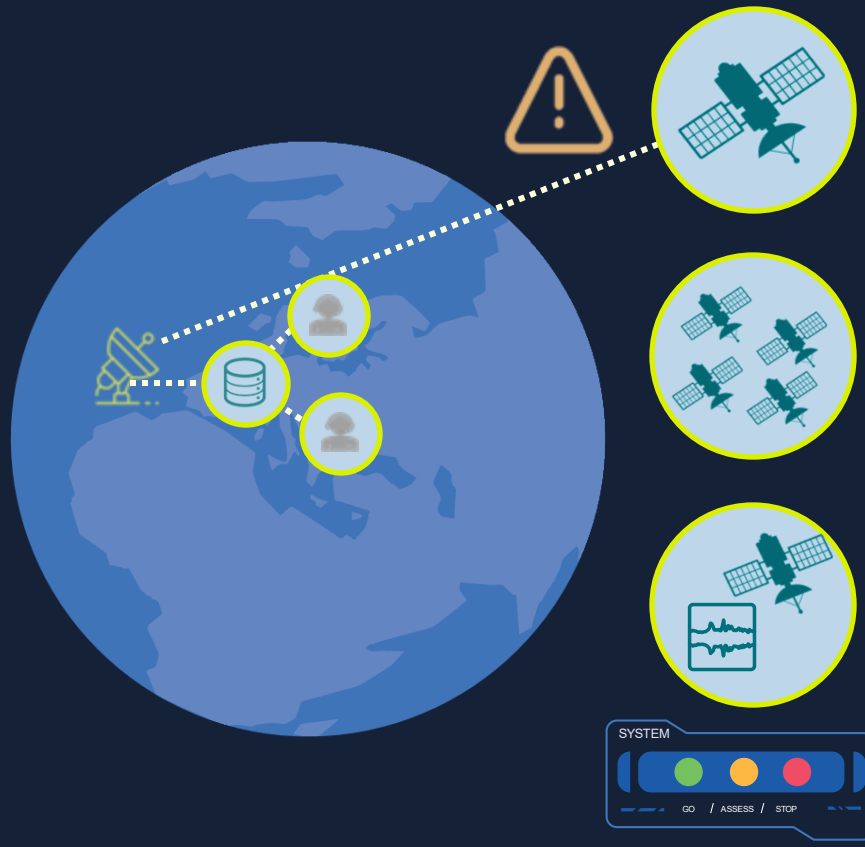
European Space Agency Benchmark for Anomaly Detection in Satellite Telemetry, Kotowski et al. 2024

https://mlcommons.org/

Data-sharing

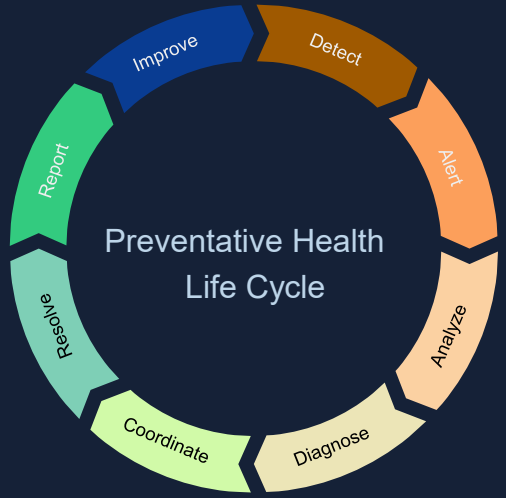
Coordinate → Resolve → Report

- Taking Health Monitoring out of isolation
  - Critical data for other stakeholders
  - Must be automated, integrated, and easy
- Distributed Communication Network
  - Standardize data format and metrics
  - Standardize infrastructure and service availability
  - Int'l coordination body
- Traffic and SSA Interface
  - Debris tracking
  - Space Weather
  - Secondary objects from collisions
  - Data for new space environment KPIs
- What about anomalies and failures?



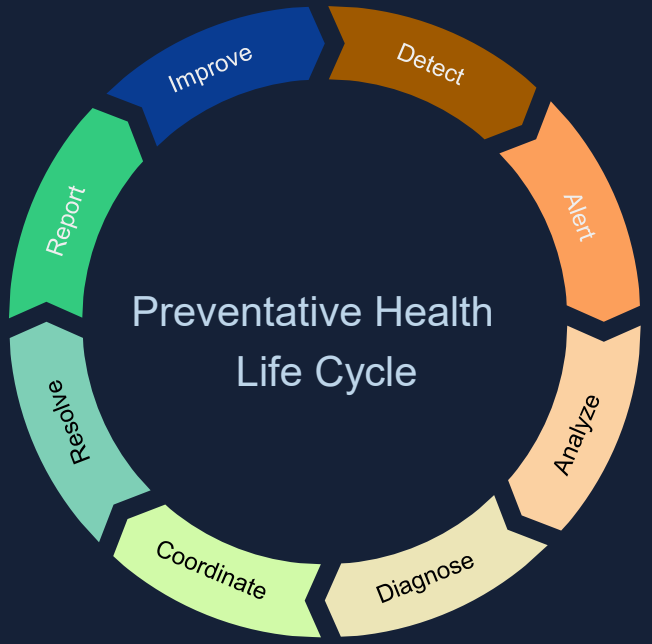
Open Source DB - Anomaly/Failure + Satellite Health

- Improving Prognostics
  - Common metrics, data-sharing methods, and automated satellite health updates
  - Improved and validated RAMS and FDIR methodologies
  - Resource Management and Mission Planning
  - Digital twins data source
- Manufacturing Benefits
  - Automated wearout and RUL capabilities across industry
  - Design validation and component quality
- AI Models - General Evaluation Framework
  - If shared in consistent and anonymized format
  - Can be used for shared KPIs, evaluations, and model development
  - Improving AI model explainability
- Anonymization is key enabler
  - Create buy-in of key stakeholder



Concluding Statements

- Health Monitoring Benefits – Best when shared
  - Health Monitoring benefits cannot be realized through isolated analysis
- AI Montoring Solutions Are Available
  - Diagnostics and prognostics are maturing
  - Require validation approach and common benchmarking
- Focus on the Interface
  - Data sharing across efforts creates a resilient ecosystem
  - Prognostics, manufacturing, traffic management
  - Must focus effort to streamline and automation
- “Open-sourcing” of Anomalies and Health Metrics
  - Anonymization and buy-in are key
  - Fuel for improvements across industry
  - Feedback for model improvement



Thank You

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