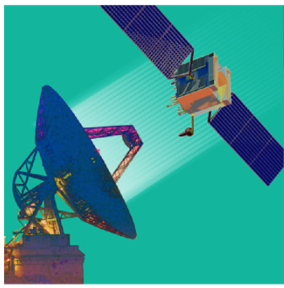
Working Group Outbrief

Ground System Architectures Workshop



Session 11F

Intelligent Systems/Machine Learning for Space Ground Systems

Nehal Desai
James Zalinski
Andrew Brethorst
Daniel Balderston
Michael Williams
Pablo Settecase
Che-I Lien

Aerospace Corporation
Information Systems and Cyber Division
Engineering and Technology Group

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Working Group 11F - Description

Purpose:

- Resilient Space Systems require timely and effective detection and response capabilities when anomalies occur. Engineering strives to define and manage foreseen anomalies, but unforeseen events and abnormalities often result in mission failure.
- Space system operations involve extremely large volumes of dynamic data that reflect nominal, expected, maturing and ultimately degrading space systems, all in a changing space environment where unforeseen events occur. Detection and response must be both timely and accurate for mission success, but must evolve with the systems, environments and actors involved. All segments are involved (i.e., space vehicle, ground control and mission data or service capabilities).
- Adaptive automation is essential for success. The challenge is finding the proper balance between human involvement and autonomy. Intelligent systems and machine learning promise to address these challenges through self-evolving, efficient, and value-focused capabilities. These systems, however are often misunderstood, misapplied or insufficient for mission needs.
- The “Intelligent Systems / Machine Learning for Space Ground Systems” working group will seek to identify and demystify where intelligent systems and machine learning currently exist in space ground systems, discover what emerging capabilities are being developed in the community, and to capture real-world impediments for adoption, and how intelligent systems/machine learning has advanced space systems resilience.

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Panel Participants

Panellist	Organization
Mr. Daniel Brennan	Senior Director, Mission Solutions Military Intel and Advanced Programs Oracle Corp National Security Group
Mr. Carlos Rexach	Senior Project Leader, Software Engineering Subdivision Aerospace Corporation Engineering and Technology Group Aerospace Corporation
Dr. Erik Linstead	Schmid College of Science and Technology Chapman University / Aerospace Corporation
Ms. Carrie Hernandez	VP of Engineering Slingshot Aerospace
Ms. Melanie Stricklan	CTO Slingshot Aerospace
Dr. Zhenping Li	Senior Principle Engineer Arctic Slope Technical Services

Analogy -- Understanding the levels of driver/vehicle autonomy

SAE (Society of Automotive Engineers) levels of autonomy

- **Level 0 (No Automation)**: Automated system issues warnings and may momentarily intervene but has no sustained vehicle control.
- **Level 1 (Drive Assistance)** (”hands on”): Driver and automated system shares control over the vehicle. Adaptive Cruise Control, Parking Assistance, steering is automated and Lane Keeping Assistance (LKA).
- **Level 2 (Partial Automation)** (”hands off”): The automated system takes full control of the vehicle (accelerating, braking, and steering)
- **Level 3 (Conditional Automation)** (”eyes off”): The driver can safely turn their attention away from the driving tasks, e.g. the driver can text or watch a movie.
- **Level 4 (High Automation)** (”mind off”): As level 3, but no driver attention is ever required for safety, i.e. the driver may safely go to sleep or leave the driver's seat. Self driving is supported only in limited areas (geofenced) or under special circumstances, like traffic jams.
- **Level 5 (Full Automation)** (”steering wheel optional”): No human intervention is required. An example would be a robotic taxi.

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The Resilience Curve – how does IS/ML help?

Bie *et al.*: Battling the Extreme: A Study on the Power System Resilience

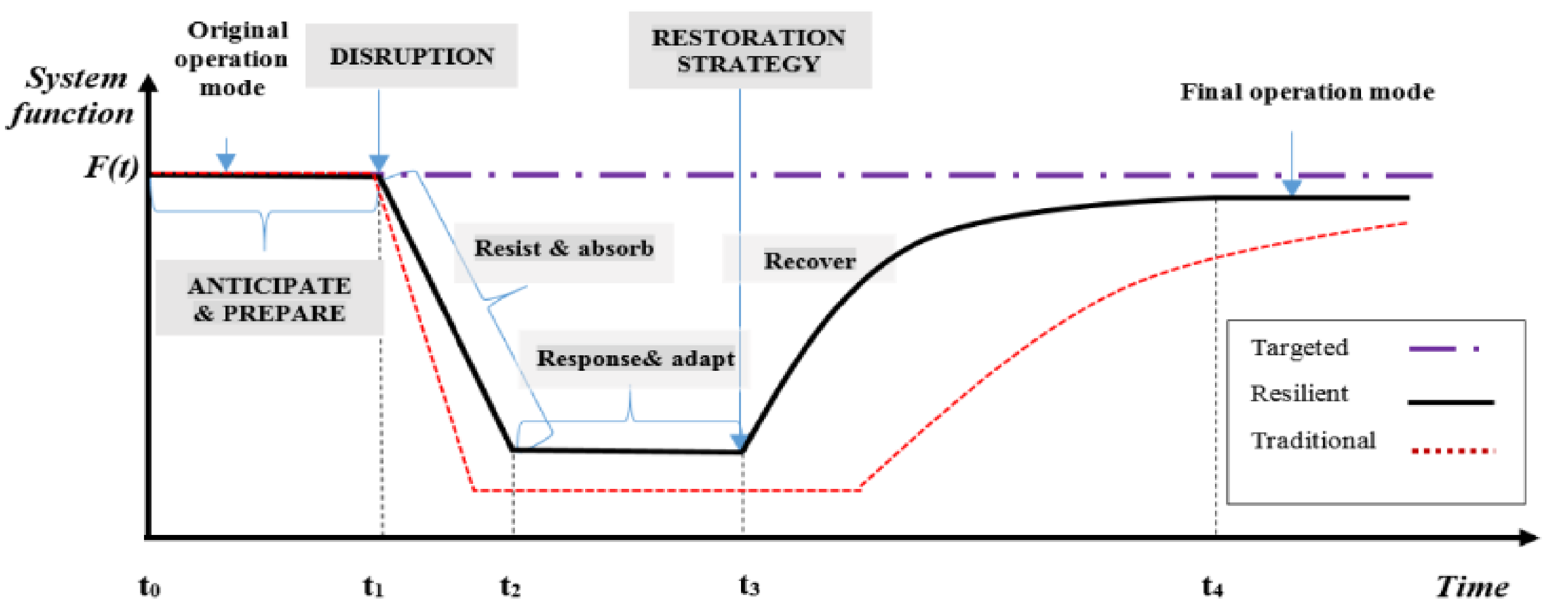

Fig. 2. *Illustrative process of a resilient power system through disruption.*

"Battling the Extreme: A Study on the Power System Resilience" Proceedings of the IEEE | *Vol. 105, No. 7, July 2017*

WG Findings - Myths

- IS/ML is not a silver bullet
  - Inappropriate applications, overly optimistic expectations
- IS/ML a black box
  - I can't understand it therefore we cannot build confidence / trust
- A "Shiny object", can be applied to anything
- Space systems are unique with regards to data analytics, operations
  - Therefore requires inventing new solutions
- IS/ML is still immature, impractical for space ground systems

WG Findings – Current Capabilities for Space Ground Systems

- Spacecraft health & safety monitoring (regression, neural-net based anomaly detection is emerging with some success)
- Mission Data Processing (Imaging, SIGINT noted)
  - Change detection, auto centroiding
- EGS / DEX (prototype)
- Commercial tools, infrastructure are applicable to space
  - "Don't waste precious resources duplicating COTS"
- Open source SW: mature, being adopted

WG Findings – Emerging Capabilities

- Tools
  - Edge computing
  - Data transformation tools and messaging infrastructure (Kafka)
- Infrastructure
  - Mirroring development and production environments
  - Integrated hardware, cloud environments
  - Data analytic frameworks (Spark, commercial products)
- Process
  - Adoption of DevOps to data analytics
  - Algorithm standardization
  - Data standardization

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WG Findings - Opportunities

- Use cases discussed for space
  - Anomaly detection on SV
  - Rapid / automated capture, enhancement and exploitation of mission data (EO, IR)
  - Large scale constellation management
    - Example: Olympic drone display
  - Constellation event correlation
- Improving timelines for resilient recovery
  - Time to: detect, diagnose, decide, respond, recover
- Prediction to avoid disruption, need for resilient recovery
- Increased insight into system behavior, performance, anomalies
- New insight and capabilities at system-of-system level
- On-board vs. ground-based analytics for greater coverage
- Knowledge capture from operators to automate operations

WG Findings – Impediments, roadblocks

- Trust in IS/ML decision
- Need tighter coupling between operations and analysts (algorithm designers
- Management / customer awareness of cost (effort) for data prep, normalizing
- Cultural resistance = change, reduction in staff, risk of automation
- Access to data
  - Silo'd data
  - Existence of data unknown
- Security enclaves
  - needed FOSS, COTS software require hard-to-get approvals
- Lack of standards
  - Tools, data benchmarking,
- Lack of qualified engineers
  - Has been esoteric, non-practical arena; now in demand

WG Findings – Successes in enhancing resilience

- Multi-INT change detection for natural disasters, DoD, insurance
- Enterprise constellation event detection (prototype)
- Operational on-line and forensic spacecraft anomaly detection and diagnostics

WG Findings – Other findings / considerations

- Need to move algorithms to data (not vice versa)
- Data management and analytics need to be integrated
- Models must evolve at rate-of-change of system / enterprise / mission
  - Must include update / sustainment / deployment cycle
- Must understand cost-benefit-risk of IS/ML outcomes
  - Probability of detection vs. probability of false alarm
- Prediction, attribution are difficult
  - Need to be problem-driven
  - Require full understanding of data for supervised training
- Supervised vs. unsupervised training

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WG Findings – Final Take-aways

- We are at dawn of operational use of IS/ML
- IS/ML for space is happening, desired, necessary, inevitable
  - Data explosion
  - Pressure for increased capability, performance
  - Race / competition (industry, national security)
- There is no alternative
- Prediction is the ‘Holy Grail’

- WG has interest in continuing at future GSAWs

To Ponder … An Intelligent 'Black Box'