Artificial Intelligence for Space Operations

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AI & Operations Innovation team @ ESOC

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What is Space Operations?

Similar to your daily routine

Keep you healthy

Be “productive” in your life
What is Space Operations?

Health Caring of Spacecraft

Productive Chain: Plan + Execute + Get Payload Data & Disseminate
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Planning
Execution
Monitoring
Forecasting
Diagnostic
AI in Space Operations: First Steps

2002 Intuition

Space Operations @ ESOC is rich in data

We can do more with these data. If we have easy access.

Thermal Virtual Sensor with Artificial Neural Network
Early AI Applications in Operations:
Fuzzy Logic for Decision Support

Ulysses Nutation Anomaly
Management Tool deployed @ JPL

ENVISAT Gyroscopes Health Monitoring Tool deployed @ ESOC
AI in Operations

How to **generate** optimal plans and get more science

How to **predict** what is going to happen

How to **detect** novel behaviour

How to **learn** from the past to better design the future
Artificial Intelligence & Operations Innovation core team
@ ESOC

Redouane Boumghar, Jose Martinez-Heras, Jose Da Silva, Alessandro Donati, Simone Fratini, Nicola Policella
Ecosystem for **easy access** to operational data: MUST & ARES
How do we detect novel behaviour ahead of failures?

Predictive Maintenance: use ML and Novelty Detection to find potential anomalies before they become serious.
How do we generate optimal plans?

Autonomous coordination and planning of payload experiments:
- Operations of 4 ESA Technology Payload on Alphasat
- AI planning & AI monitoring technology
How do we predict the consumption of MEX thermal subsystem next year?

Added value: Accurate power consumption prediction enables more resources for science.

Winning team from Jožef Stefan Institute in Ljubljana, Slovenia
How do we learn from the past to better design the future?

TEC-MUST, a data analytics platform and service to support inter-directorate:

• Multi-Spacecraft performance assessment
• Collaborative diagnostics
• Design models fine tunes
• Close-loop btw development and operations
Dependency Finder plus Visual Analytics

Spotting of unexpected coupling:
- update of ops procedure
- feedback to design
How to identify critical conjunctions autonomously?

e.g. Oneweb:
- 720 spacecraft
- Up to 100 collision alerts per spacecraft every day
- 30 parameters per alert to be analysed by human experts
- => more than a million data points to be considered for collision avoidance action day and night!
- => planned ARTES study on autonomous decision taking
AI Planning & Scheduling: Self-organizing EO Constellation using Ant Colony Optimization Paradigm

**Coordination mechanism:** 3 DMC3 spacecraft, Multiple GEO spacecraft

Self Organization

Ants community

Spacecraft community!

Evaluation of how well all s/c performed

Objective function: \[ f(S/C \ 1, \ S/C \ 2, \ ... ) \]
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Amount of pheromone decided based on the performance of the group

Act as a unit, not separate S/C
OPS-SAT experiment: AI for Autonomy Operations

Demonstrate the capability and maturity of AI planning and scheduling

- to **autonomously schedule and re-schedule onboard activities**
- based on
  - awareness of **current situation**
  - on pre-loaded **operations goals**

Built on “Advanced Planning Scheduling Initiative” (APSI)
ESA Open Source Platform
Random Forests to predict the ESA News #views

Random Forest provides accurate predictions but ...

The ESOC Communication Office is looking forward to understanding what engages the public

http://www.esa.int/Our_Activities/Space_News
Spin-off of AI in Operations

Health Caring of Spacecraft

Health Caring of Humans

Collaboration with ESA Astronauts Medical Team

Collaboration with Merck
Machine Learning Workflow: where the effort goes

- Problem Understanding
- Evaluation Criteria
- Prepare Data
- Train model
- Error Analysis
- Baseline
- Production Trained Model

Effort

- More complex model
- More data / features
- Better problem understanding
- Better baseline
- Production Trained Model
AI for Space Operations: Way forward

- Share experiences to help & sustain AI potential exploitation in
  - Spacecraft operation
  - Spacecraft design
  - Payload products & services

- Next Themes for Space Operations:
  - Explainable AI
  - AI for Autonomy
    - On ground (e.g. ground stations)
    - Space + Ground (one entity)
Artificial Intelligence in Operations

D/OPS experience & perspectives

- 15 served missions, incl. Galileo
- 10 AI applications in operations, incl. 2 patents and 1 invention
- 4 in-house AI specialists with deep operations knowledge
- Cooperation with other directorates, national & int. space agencies & int. organizations
- Networking and support with Academia and Industry to spread AI for space applications

Spin-off: dissemination, consultancy
AI for Space Operations and more - Take Away

- AI is now an integrated part of Space Operations
- From ground to onboard as a new space-ground unified asset
- **Collaborative AI** is becoming a field for Data Scientists across Spacecraft & Mission lifecycle (concept, design, production, operations, dissemination)
- *Easy access to “good” data is imperative*

Thank you for your time
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