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Constellations Operations : Challenges…and ambitions !

30 & 31 Mars 2023 CNES COMET « Opérations du futur »

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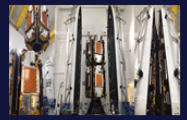
(MEGA) Constellation operations challenges at a glance…

Globalstar O3b Networks **Lessons Learned** iridium

1st LEOP AUTO Sequence



Save Time

Design Robustness

Multiple critical contingencies recovered successfully

Constellations Operations

Multi Skilled People

Reduce OPEX

Flexibility

Innovative Operational Concepts

NOT ACHIEVABLE with "standard" processes !

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(MEGA) Constellation operations challenges

OPEX : MORE WORKLOAD, MORE PEOPLE, MORE GROUND STATIONS…

Constellation Deployment = “Space Marathon”

- Challenging schedule needs flex & trained people !
- Don’t forget to manage the birds “already flying”!
- **Potential CONTINGENCIES**

Ground Resources Management

- Potential lack of accessibility
- **Overlap operations = “BOTTLENECK EFFECT”**
- Adding more Ground Stations will not solve potential **TM/TC interferences !**

MAINTENANCE COSTS : Certifications, tools & TURNOVER !

- **Personnel to train /to hire**
- **Maintain competencies**
- Ground/board Tools to be maintained

PRICEY & TIME CONSUMING !

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(MEGA) Constellation operations challenges

SAFEFY & SECURITY

> Prevent **COLLISION** in orbit !
  - LEO Orbit congested

> Prevent **CYBER attacks** !
  - Less HW, More SW

SUSTAINABILITY

> **« PREVENT before to ACT »**
  - Best way to reduce workload !

> **Protect Earth and Space….and SPACE BUSINESS !**
  - **Responsible OPS behavior** to reduce environmental impact
  - LOS, **SSR** (**S**pace **S**ustainability **R**ating)

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Constellations Operations Tomorrow …

SUSTAINABILITY

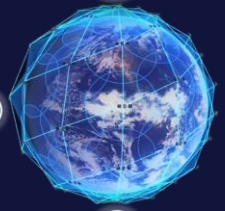
3

SECURITY

+

SAFETY

2



1

OPEX

Autonomous Systems 1

Analytics 2

Anomaly detection characterization prediction 3

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3

Board

Ground

Satellite Operations

delfox PREDICTIVE TECHNOLOGIES

2

exotrail end-to-end space mobility

1

YOU ARE HERE

MANUAL

Globalstar

iridium

O3b

AUTOMATION

Cyber Security

OpenSCC

Edge

« SatDevOps »

Cloud

AUTONOMY

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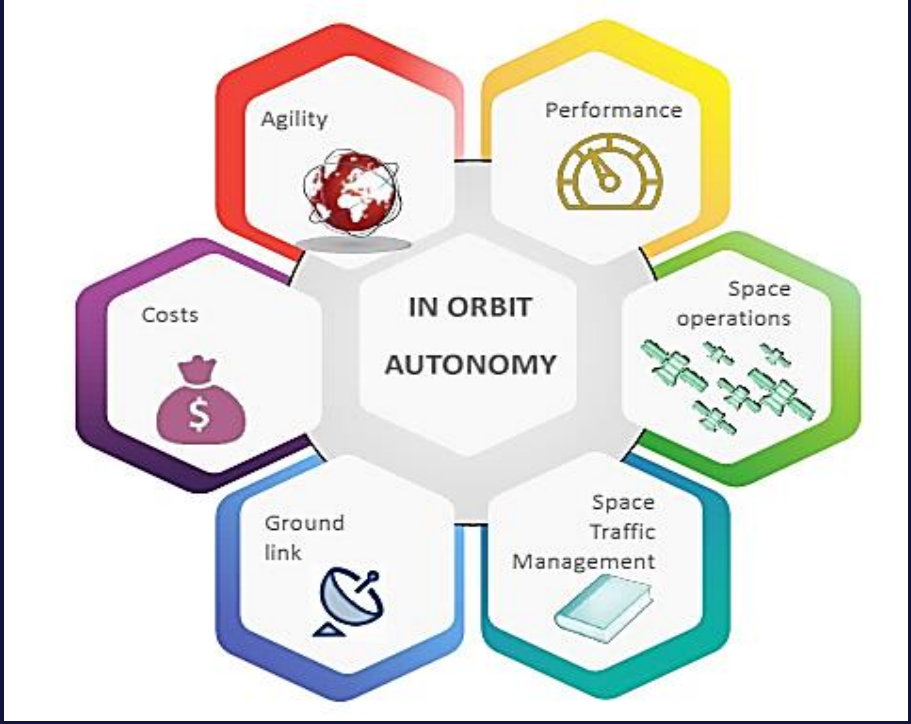
What impel us to work on in-orbit autonomy ?



A CNES-TAS COMMON SHARED VISION !

01 – AGILITY
Satellites and Missions become more complex.

02 – PERFORMANCE
To reach a NEW LEVEL of performance (ground/board operational loop reduced)

03 – SPACE OPERATIONS
More Satellites makes GROUND management more difficult.

04 – SPACE TRAFFIC MANAGEMENT
SAFETY needs to be guaranteed while respecting shared rules in a efficient way

05 – GROUND LINK
Ground is expensive…ground stations network is already at a **CRITICAL point for constellations**

06 – COSTS
Constellations Space Programs COSTS are now requiring a high level of autonomy !

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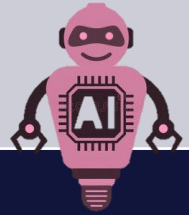
Level of autonomy for satellites operations : Where we are ?

Yesterday

Today

Tomorrow ?

Level of automation	On GROUND	On BOARD
LOW – Satellite or Fleet of satellites	- Operational procedures scheduled for each satellite on each phase - Permanent presence of Controllers & Experts	- Very **LOW on-board autonomy**, - Mainly automatisms for **satellite SAFETY**
MEDIUM – LARGE constellation (<100)	- ROUTINE operations scheduled (AUTOMATION) - Controllers 24/7/365. Experts in "office hours" - Additional Controllers & Experts on call	- **More automation** onboard (Event Action, Action Sequences, LEOP Auto Sequence, etc) - Execution of **Onboard Control Procedures**
HIGH – MEGA constellation (>=100)	- Automate ALL phases ? - **A Multi-tasks Operator** ? - A "**virtual assistance**" (**AI**) mode **"ON DEMAND" ?** - **Rely on CLOUD for additional Ground resources "ON DEMAND" ? (SW, HW, AWS GS, etc)**	**Toward A "SMART" AUTONOMY ?** - **AUTO Maneuvers/collision avoidance** ? - **High Computing capacities** + **Edge/Cloud env** + **AI/ML to improve operations**, - Anomalies prediction with **AI** ? - **Autonomous Analysis** to ease decision making process ? - **Automate onboard recoveries** ?



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Collision Avoidance Solutions TODAY : "state of the art" at a glance

« DIY »

CSM: conjunction summary message
Envoyé 72h avant le TCA (time closest approach)
Miss distance 1km
Velocité, dispersion, caractéristiques des orbites

SpaceTrack (JSPOC) ⇄ Satellite owner/operator

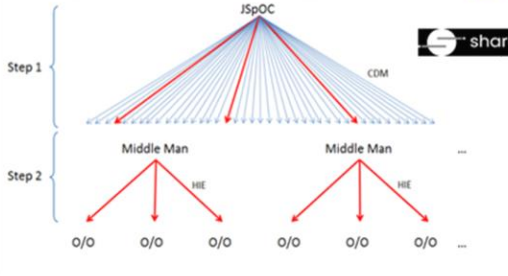
O/O sat ephemeris (daily basis)

- Entretien d'une bdd de TLE publique et gratuite
- Entretien d'une bdd d'ephemeris (données opérateurs) (catalogue SP)
-> partagée avec les agences spatiale
- Calcul des probabilités de collision toutes les 8h sur 7 jours et envoie de CSM/CDM (précision à 100m)
- Quand un opérateur propose une manœuvre, retour dans les 8h

- Evaluation du niveau de risque de collision selon ses propres critères
- Déduction des HIE « high interest event » (5% du temps)
- Décide de faire ou non la manœuvre
- Calcul de la manœuvre , proposition au JSPOC pour check et implémentation si retour positif

« Middle Man »

LEO LABS



caesar cnes NASA share my space gmv

COLA OPERATIONS – Automation & AI/ML

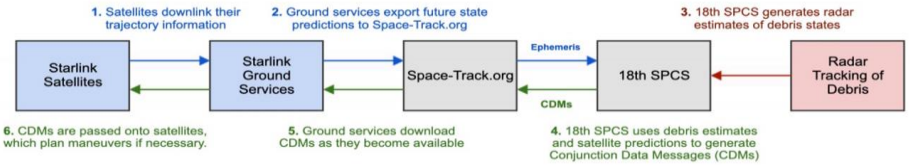
- Given enough input data, a **Machine Learning (ML)** algorithm can be trained to reproduce similar outputs as a human
- **Training data**: CDMs and other ancillary info along with the decision made
- **Additional training data** can be obtained by means of **simulation (*digital twin*)**
- **Decision parameters** and different decisions to be identified and deeply analysed
- Each **operator could train the system** based on its own needs, interest and experience **with its own data**

« ADVANCED AUTONOMY »

Collision Avoidance: Starlink-on-Debris

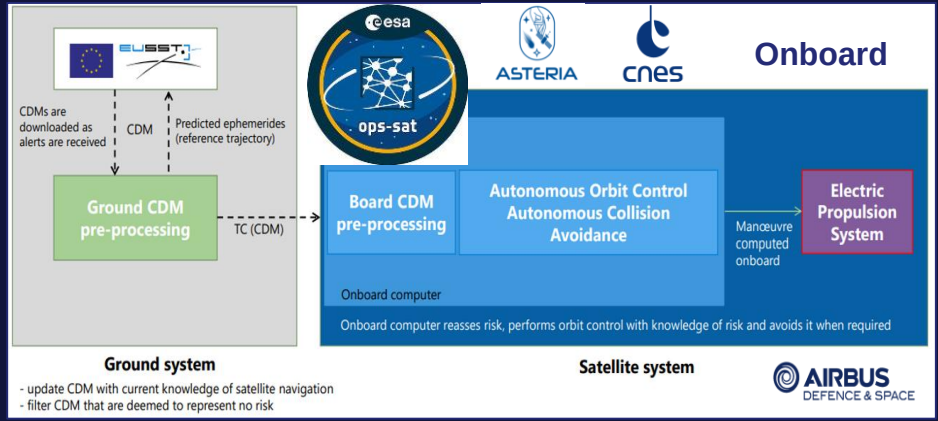
SPACEX

- Space is populated with existing debris, tracked by the 18th Space Control Squadron.
- Starlink utilizes an automated collision avoidance system, ingesting data from the 18th
  - Satellites can autonomously evaluate risk and plan avoidance maneuvers, without human input
  - Humans are still present in an oversight role, as an added measure of safety



Onboard

EUSST esa ASTERIA cnes



Ground system
- update CDM with current knowledge of satellite navigation
- filter CDM that are deemed to represent no risk

Satellite system

AIRBUS DEFENCE & SPACE

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ANOMALY PREDICTION : Toward a « Smart » FDIR ?

2023 — TAS Operation

2025 — Concept "SMARTOPS" & Ground Segments

2030 — "SMART" On board FDIR

20XX — Satellite Autonomy

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Constellations OPERATIONS Tomorrow : TAKE AWAY !

CAPEX & OPEX reduction…while maintaining SAFETY & SECURITY ???

> **"HOT TOPIC " for constellations !**

Increase AUTONOMY… & FLEXIBILITY !!

Still some issues and technological gaps to address :

- Computing capacities onboard are still limited…but "**Space Edge Computing**" could be an answer !
- **Create a transparent Cloud environment between GROUND and BOARD**
- Genericity vs Mission Specificities ???
- Contingencies ?? Ground « Backup Solution » needed if onboard system FAILED….

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THANK YOU !
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L'automatisation des opérations de constellation

exotrail
end-to-end space mobility

Suite logicielle intégrée, orientée constellation

spacetower™

- Simplifier l'intégration systèmes tiers (GSaaS, SSA)
- Améliorer la productivité / se concentrer sur les tâches à valeur ajoutée (mission)
- Changer de stratégie d'acquisition des solutions (CAPEX vs OPEX)
- Augmenter la taille de la constellation, pas le nombre d'opérateurs au sol

Contrôler → Préparer → Exécuter

FDS intégré	Nativement Cloud
Approche Produit (SaaS)	Modularité (API)

AUTOMATISATION, OPTIMISATION

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Delfox

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