ASTERIA IN-ORBIT TESTING ON OPSSAT: AN ON-BOARD AUTONOMOUS ORBIT CONTROL SOLUTION INCLUDING COLLISION RISKS AVOIDANCE

36TH ANNUAL SMALL SATELLITE CONFERENCE - SSC22-VIII-02

10/08/2022
Logan, UT

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ASTERIA

esa
ops-sat

cnes

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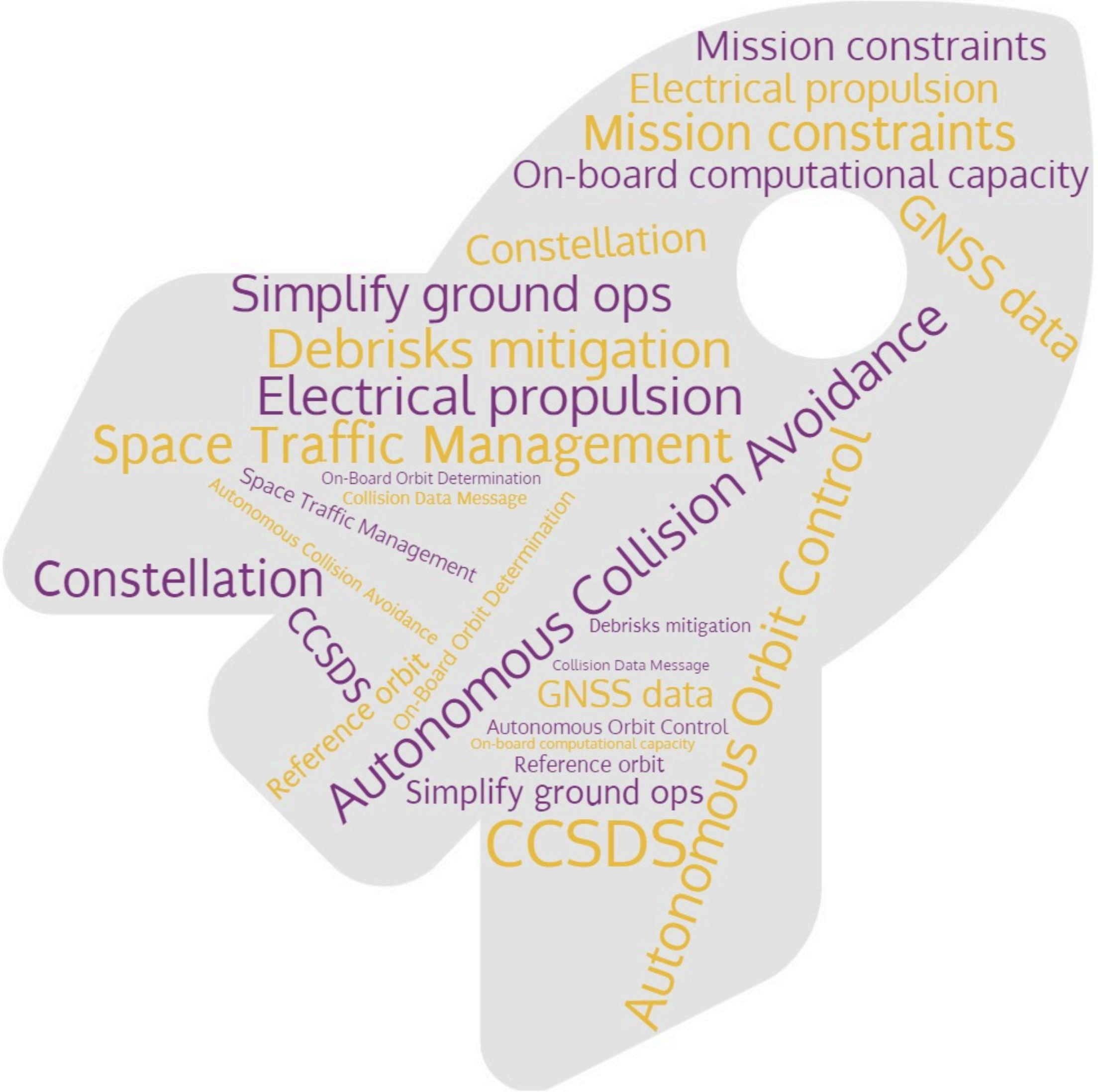
ASTERIA PRINCIPLE

AOC principle

- best reactivity
- more anticipation
- better mission programing satisfaction



ASTERIA

PATRIUS

Java

AOC principle: controllers

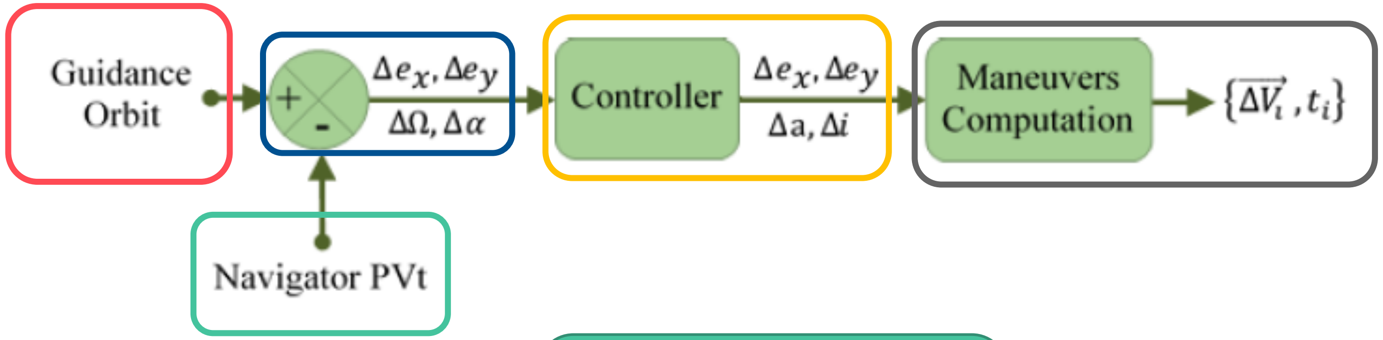
- 2D reference orbit (Ωlong, α) with J40*40 Earth potential effects

- 1D guidance orbit (α)

$$\begin{pmatrix} a \\ e_x = e\cos\omega \\ e_y = e\sin\omega \\ i \\ \Omega \\ \alpha = \omega + \nu \end{pmatrix}$$

Polynomial curve fitting comparisons on orbital deviation and their derivatives

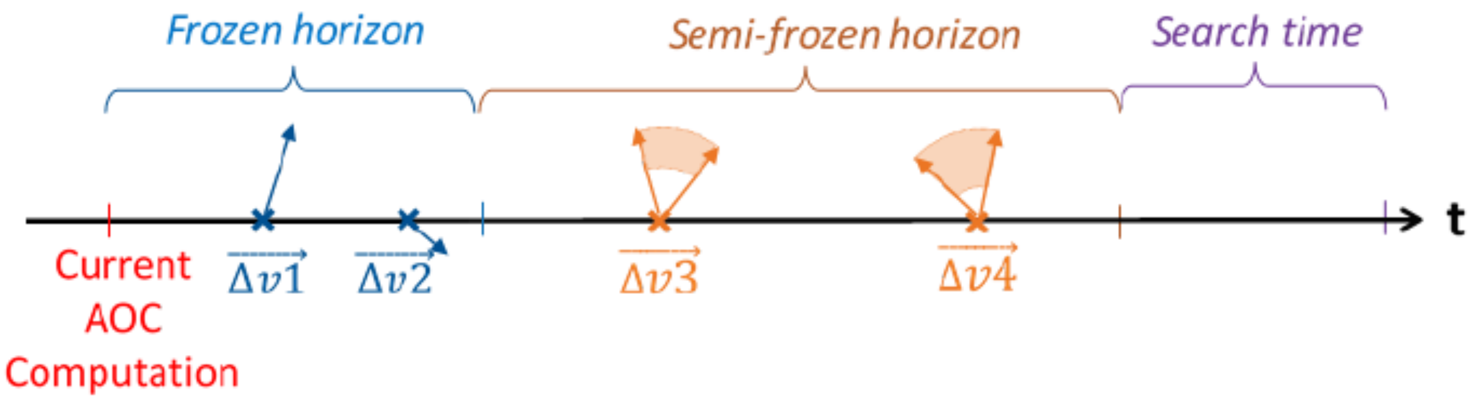
In-track and out-track controllers using Gauss analytical propagation and same polynomial curve fitting integrator (all perturbation forces) to deduced orbital increments

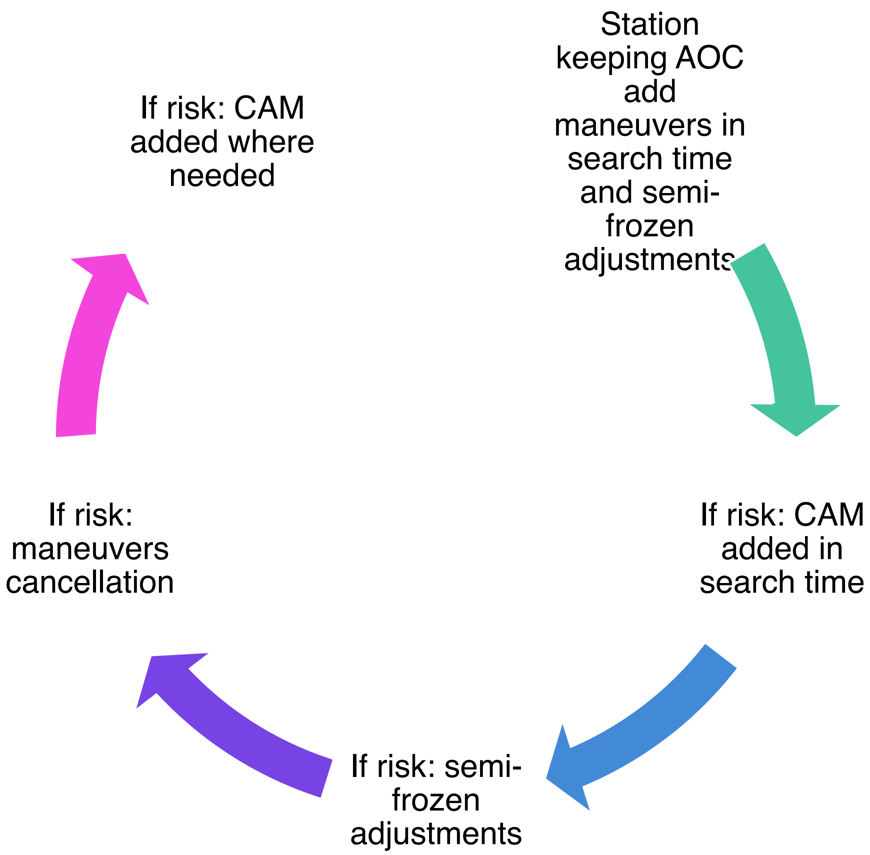


Orbital increments conversion into commanding maneuvers

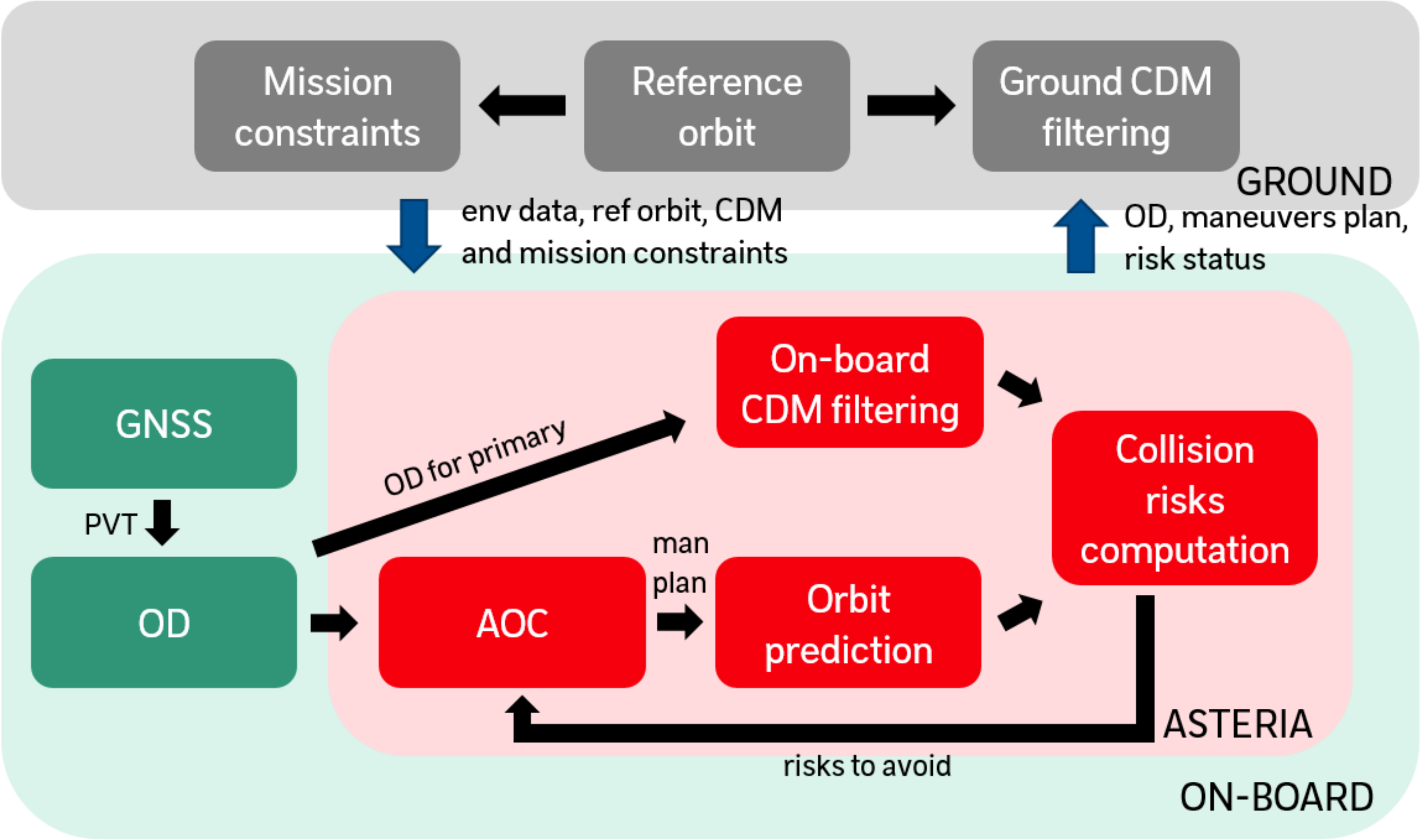
OD using GNSS and last squares method (all perturbation forces)

AOC principle: horizons

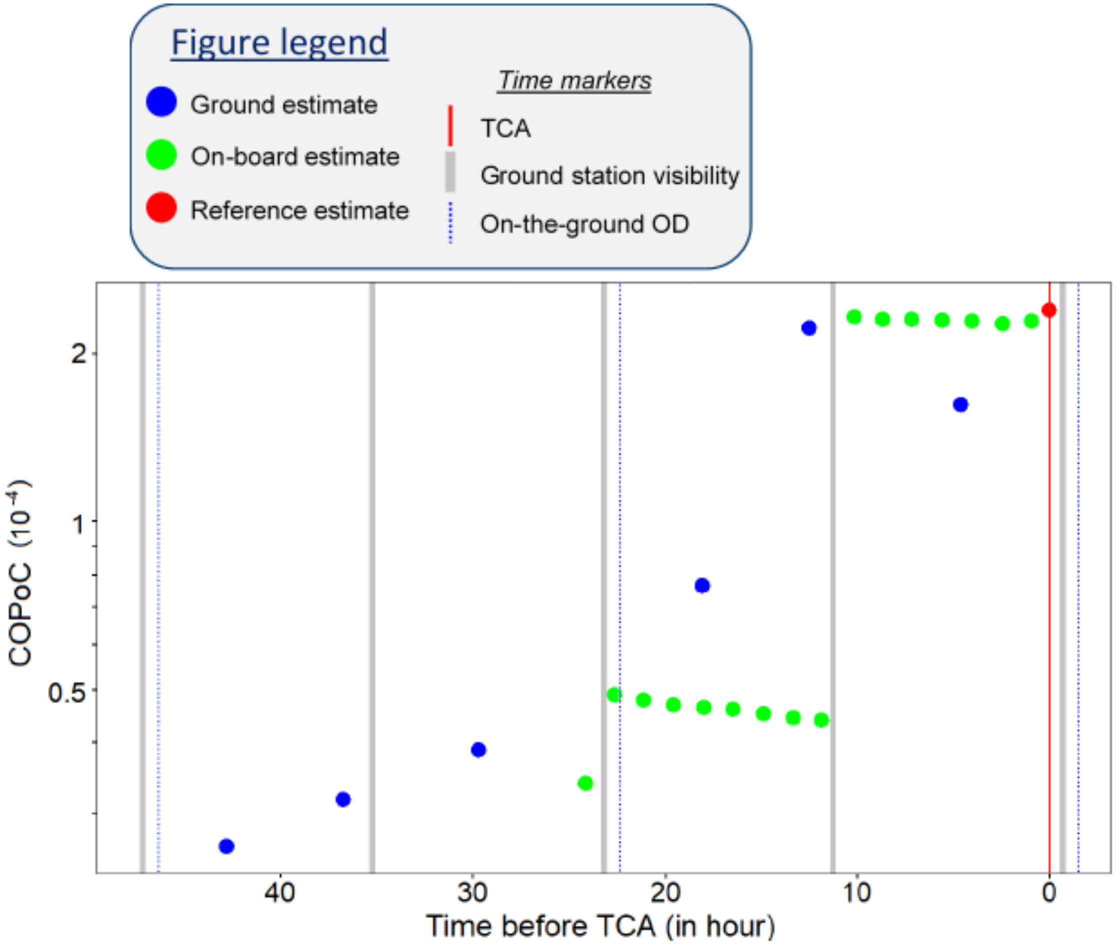




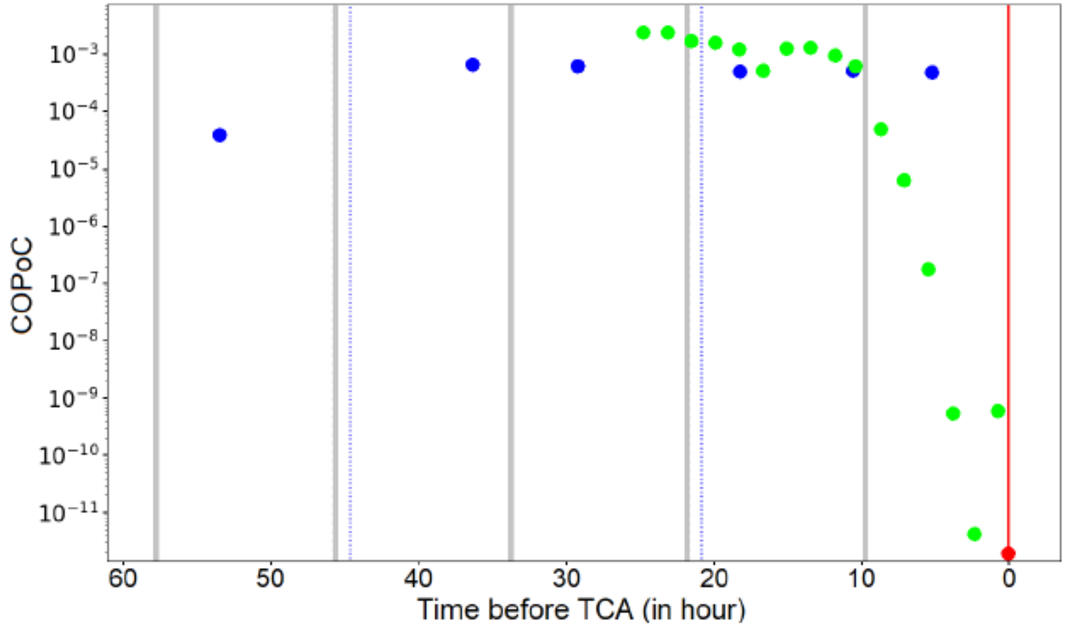
AOC – ACA coupling



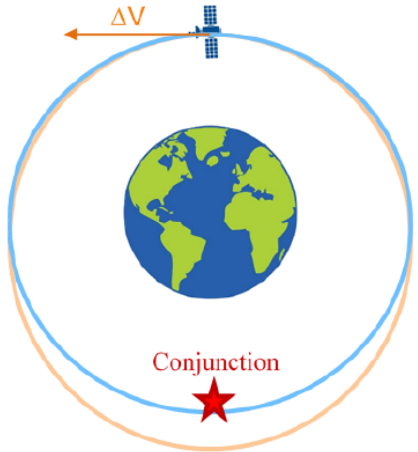
Risk mitigation



Conjunctions without CAM



Conjunctions with CAM



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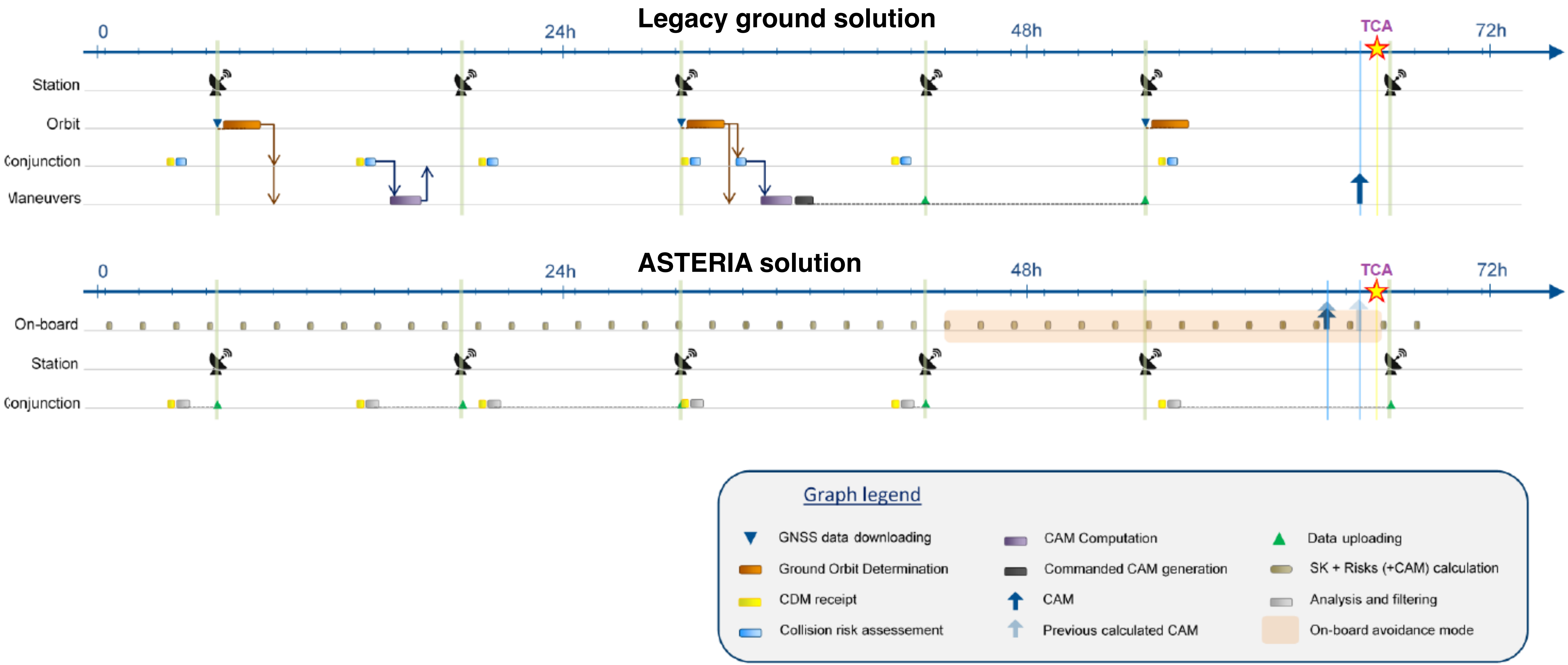
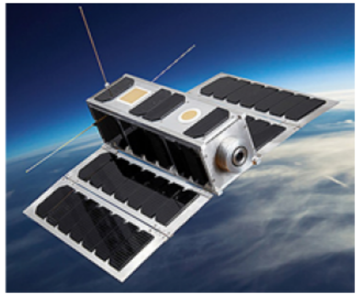
ASTERIA CONOPS

CONOPS comparison



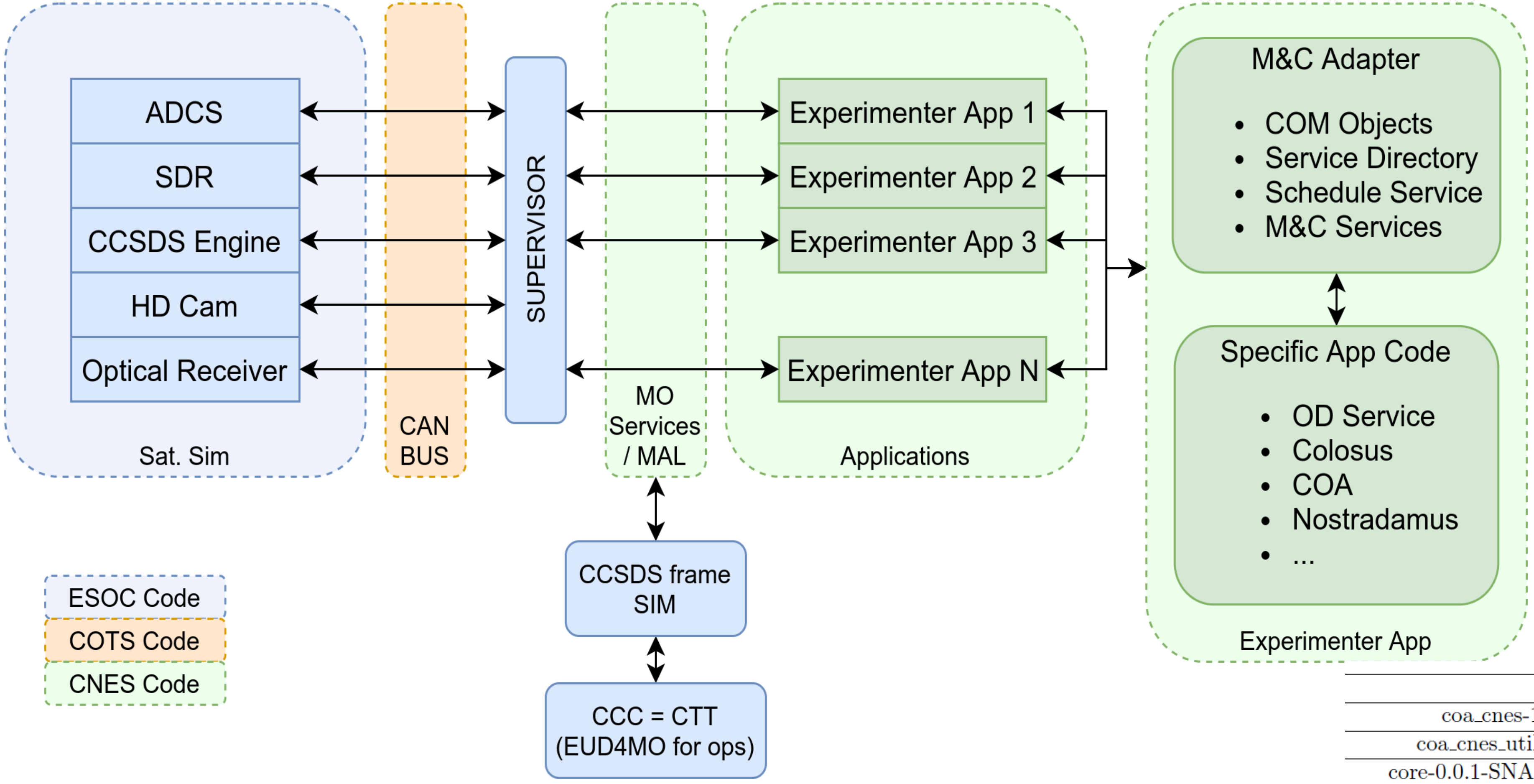
OPSSAT EXPERIMENT

OPSSAT a flying laboratory



- High computation capacity: ARM dual-core Cortex-A9 800MHz / 1Gb / SD Card 16Gb
- SSO 6h LTAN – 515km
- Java compiler
- Open-source NMF (Nanosat CCSDS MO Framework)
- Java SDK + simulator + mission control segment NMF
- Remotely web based operations with EUD4MO mission control segment NMF

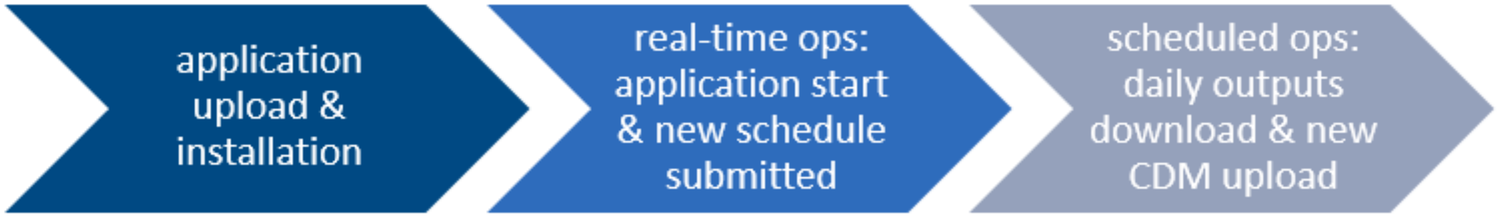
OPSSAT application architecture & packaging



ASTERIA package	
coa_cnes-1.0.jar	87 Ko
coa_cnes_utils-1.0.jar	29 Ko
core-0.0.1-SNAPSHOT.jar	120 Ko
asteriaApp-0.0.1-SNAPSHOT.jar	139 Ko
patrius-4.4.jar	4 320 Ko
opssatConfigASTERIA.zip	750 Ko
TOTAL	**5.32 Mo**
Compressed ASTERIA package	
asteria_1.93_cnes.zip	**4.92 Mo**

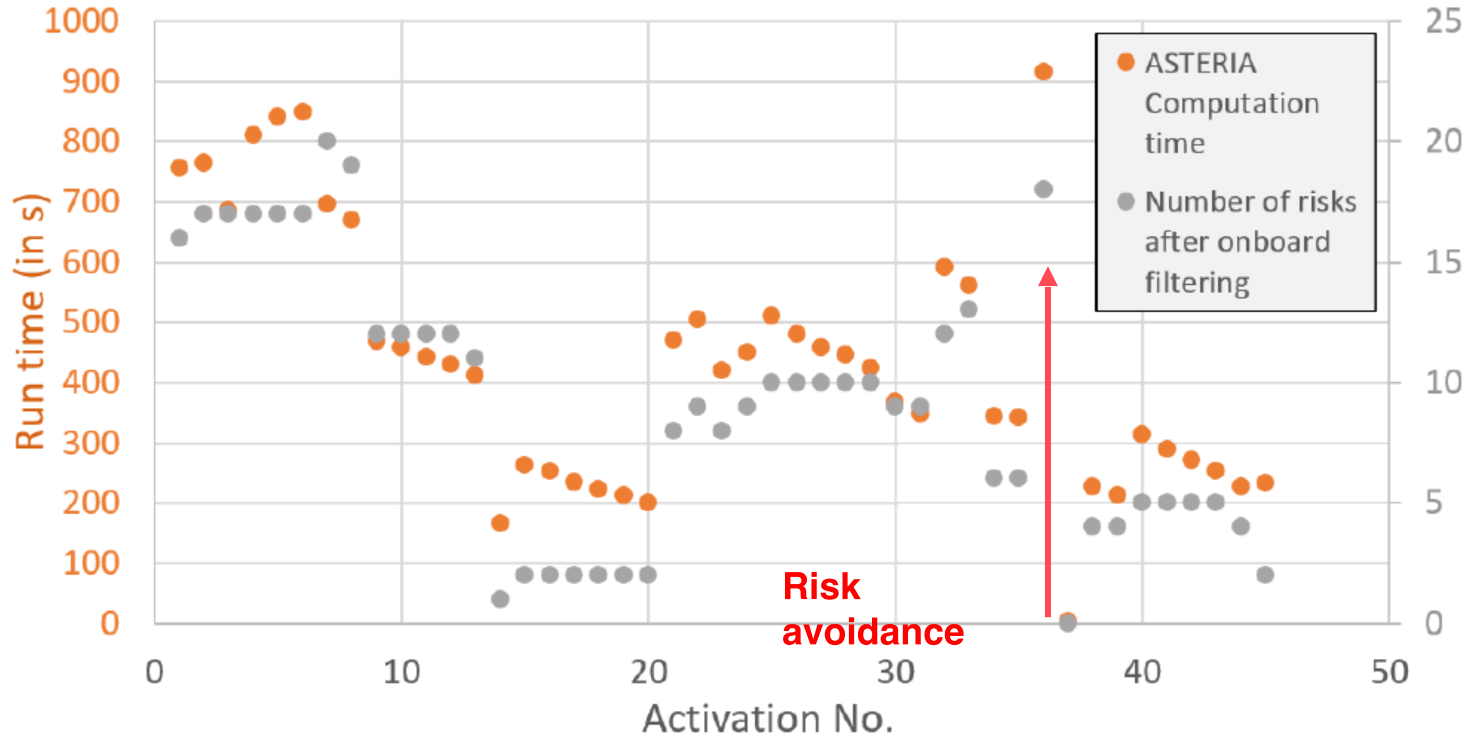
Experiment ops

- Ref orbit SSO closed to OPSSAT one
- Propulsion hypotheses: electric 25mN, ISP 2100s, Robbins penalty 95%
- 3 days testing + 20 CDM + 1 risk covering all sub-modes (risk threshold $5e^{-5}$)

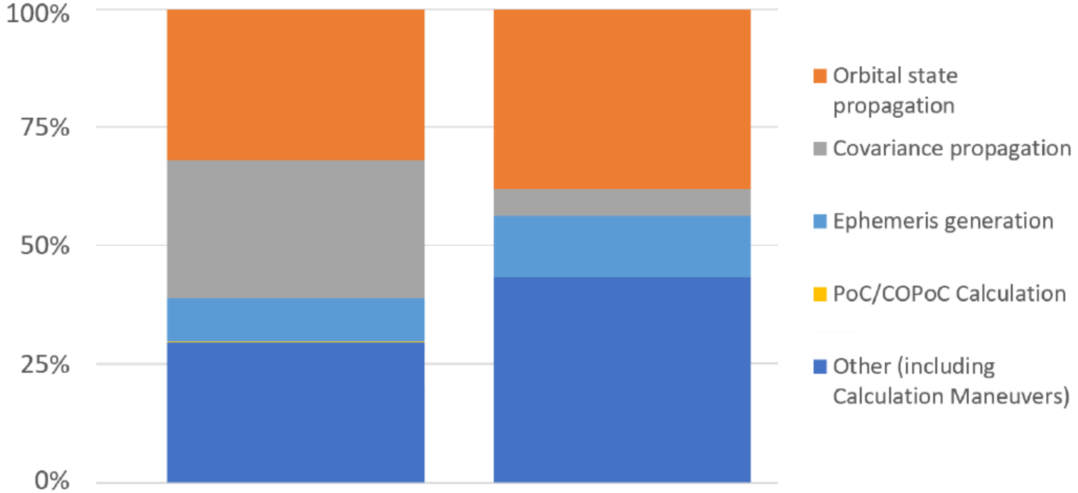


Experiment results

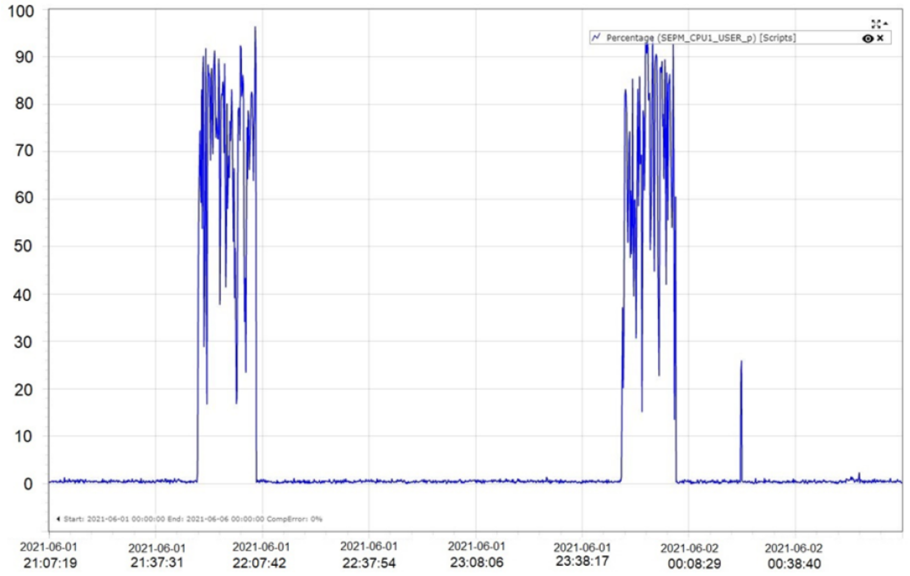
Running time at each ascending node activation



Experiment results



Computation time distribution



CPU charge examples

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CONCLUSION

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Conclusion & improvements

ASTERIA considerably increases on-board autonomy by coupling AOC & ACA with a relevant solution

First flight tests with OPSSAT show CONOPS and OBSW packaging feasibility

On-going improvements:

- Multi-risks management
- Legacy OBSW architecture coupling
- “road traffic standards” for risks with maneuverable satellites
- Flight tests with maneuvers: CNES demonstrator ?

With the multiplication of constellations and the improve of on-board computing capacities such solutions are the keys for a global Space Traffic Management !

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THANKS

ANY QUESTIONS ?

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ANNEXES

CDM:


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▼<body>
 ▼<relativeMetadataData>
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   <SCREEN_EXIT_TIME>2021-01-19T18:44:06.343</SCREEN_EXIT_TIME>
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    <INTERNATIONAL_DESIGNATOR>1989-061X</INTERNATIONAL_DESIGNATOR>
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```

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2D ref orbit:

```
# Parametre: inc
# Unite = rad
# ----------------
# Partie centree = polynome : A0 + A1*(t-t0) + ...
# t0 (date calendaire arrondie a la milliseconde, TAI) = 2020-10-11T14:09:34.648
# t0 (MJD sec, TAI) = 59133 50974.647668158934
# Coefficients : A0 A1 ... = 1.7012267403760044
# ----------------
# Partie harmonique: amp * cos(n*psoMc + k*lnac + phi)
# Col 1: n
# Col 2: k
# Col 3: amp
# Col 4: phi (rad)
 2  0 8.9584767535509670e-05 -3.1415924674331603
 0 -2 3.5933800200981624e-05 -0.41972588715494030
 1 15 5.3395733316822300e-06 0.0062277118672540155
 0 -3 3.7442438650549870e-06 1.2256364909808468
 1  3 3.4851328902479032e-06 2.0137995296267590
 0 -4 2.8771748627472514e-06 2.8399422338325664
 0 -1 2.7586497001746490e-06 -0.83171073675328340
 1  2 2.4750204571291408e-06 2.0784064684898063
 1  5 2.2780072833139704e-06 -1.7784622674219435
 1 -3 2.1424603358505672e-06 1.1503667993195634
 0 -5 1.8056113647735640e-06 -0.55070466832325590
96 1454 1.5458246620402817e-06 2.8343391944472387
 1  6 1.5437105697774738e-06 -0.80298567875867730
 1 13 1.4285683625937824e-06 0.93200296324314280
 1 -5 1.3470934231150736e-06 -1.2805927984378869
 2 30 1.2839841542947211e-06 2.9902345952844060
 1  4 1.2105485288893848e-06 -1.6586187199341111
 1 12 1.2079072152922358e-06 -0.38631231044269754
 2 -2 1.1858398512962756e-06 -0.55393132387573200
 2  2 1.0384737090501953e-06 -2.3085368744877517
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 0 -6 7.8424166503551520e-07 -1.8581966660768430
 2  5 7.7983679668607580e-07 -2.6405746292344430
 1 11 7.7700448779270280e-07 -2.1116393322778180
 0 -8 7.6066971024758710e-07 2.4978238714396497
 2 -3 7.2278287501875570e-07 -1.8295537216282050
 1 -1 6.8469024742822690e-07 0.11080491841193485
 1 14 6.7924798066592640e-07 -3.0282710851407300
 3  1 6.4441745268458500e-07 -0.11454152759931269
96 1452 6.1681514401137640e-07 -0.63625968496944550
 1  9 5.7852603423436680e-07 0.87539013075627280
 2  4 5.7343774600464280e-07 1.8146315216165796
 3 -3 5.5386137452833900e-07 1.0434712579493652
 3  3 5.2874577879647290e-07 2.2804431002466250
 0 -10 4.6635588784146276e-07 -0.17113235767580193
96 1453 4.6530251100297665e-07 1.5233537181638894
 2  6 4.5316153756974875e-07 -1.7920838943958906
 0 -9 4.3591815211665130e-07 1.5751792447632198
```

In plane

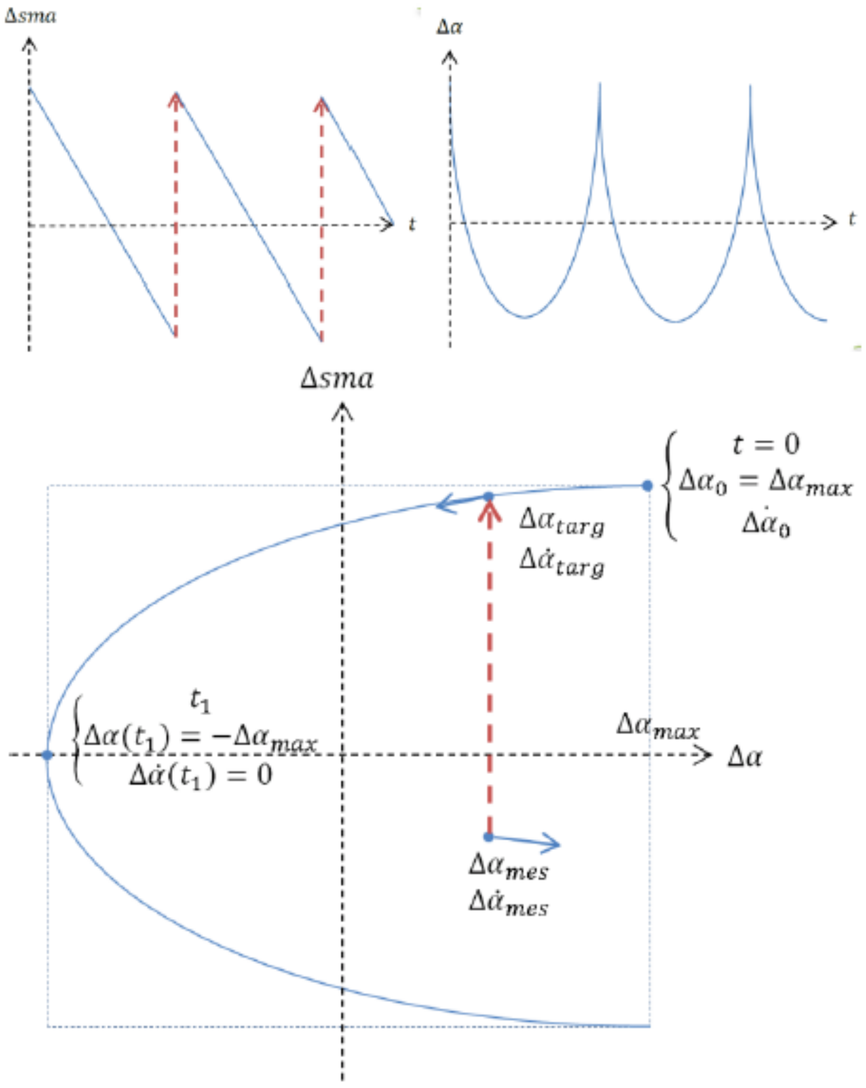

Fig. 3. Semi-major axis maneuvers strategy.

Out of plane evolutions:

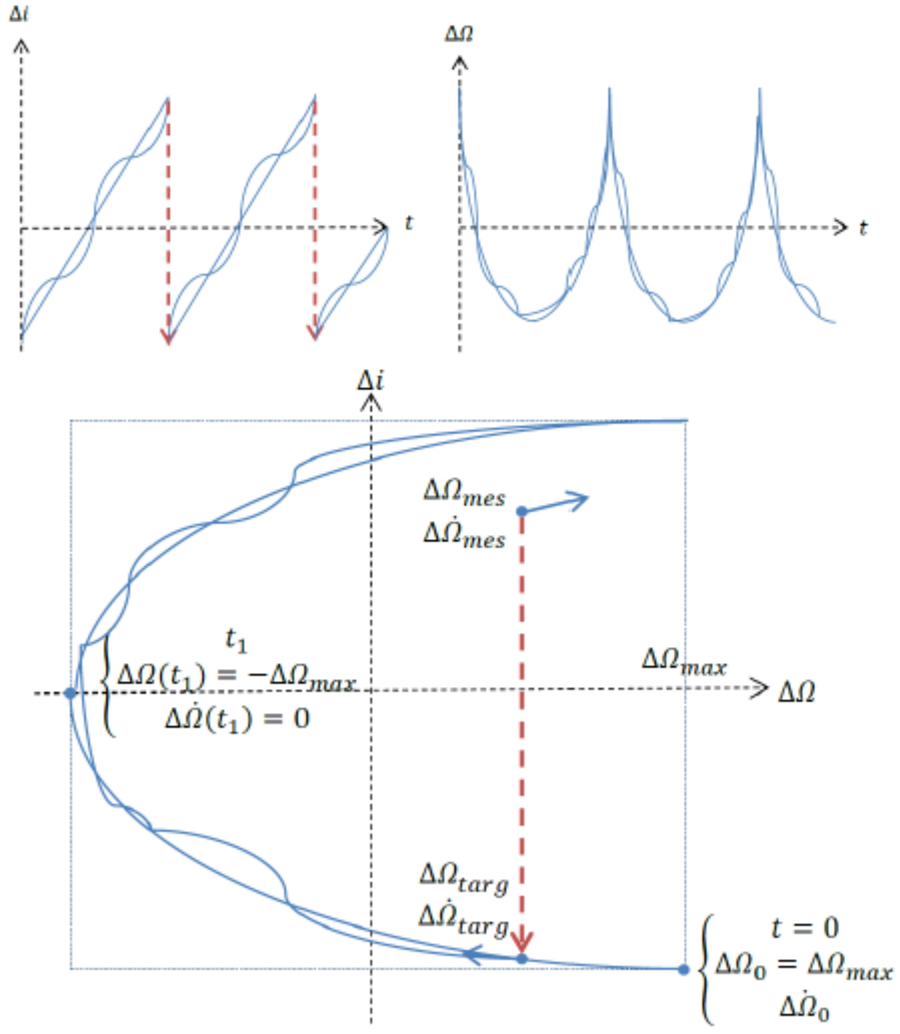

Fig. 2. Inclination maneuvers strategy.

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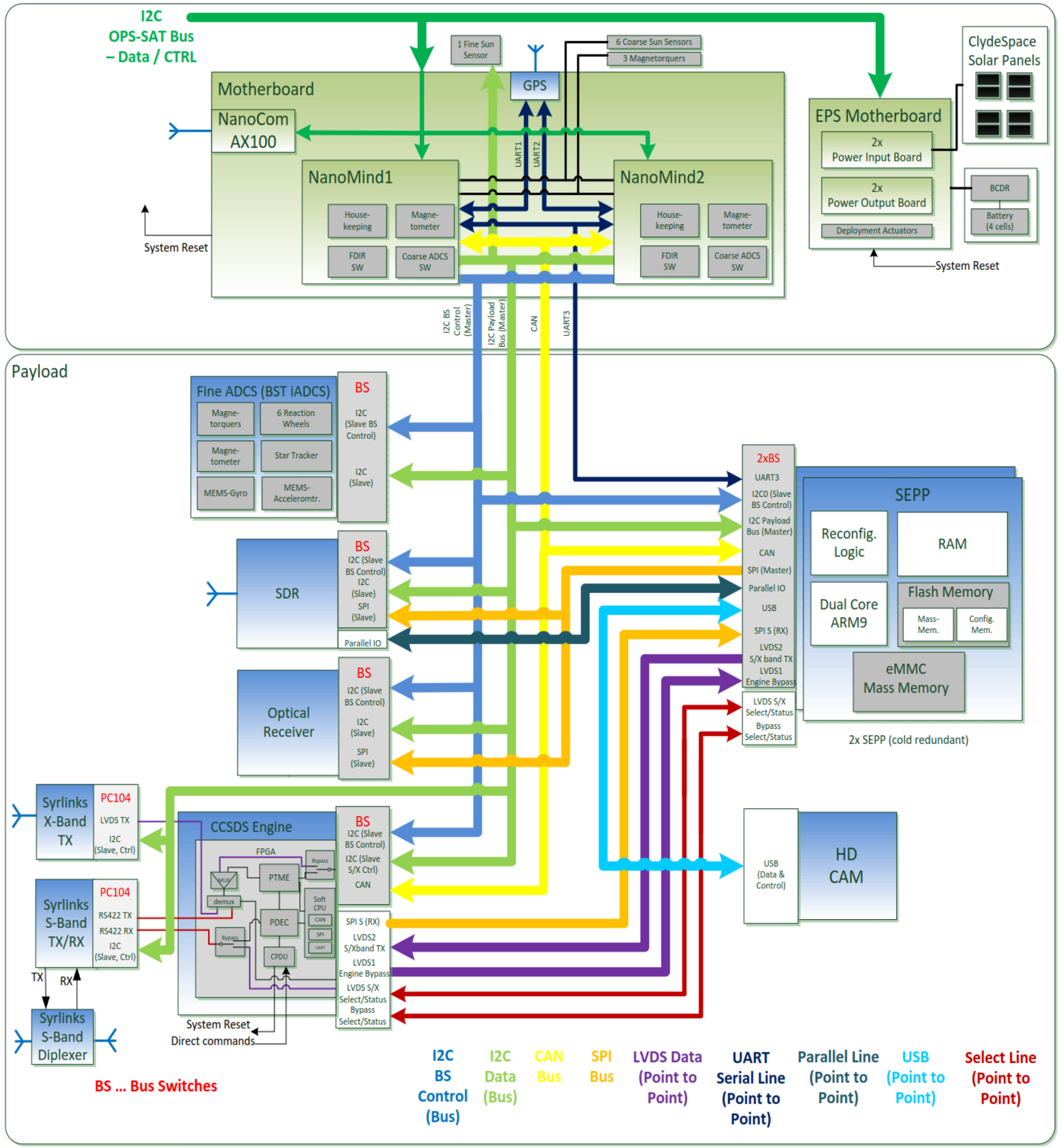
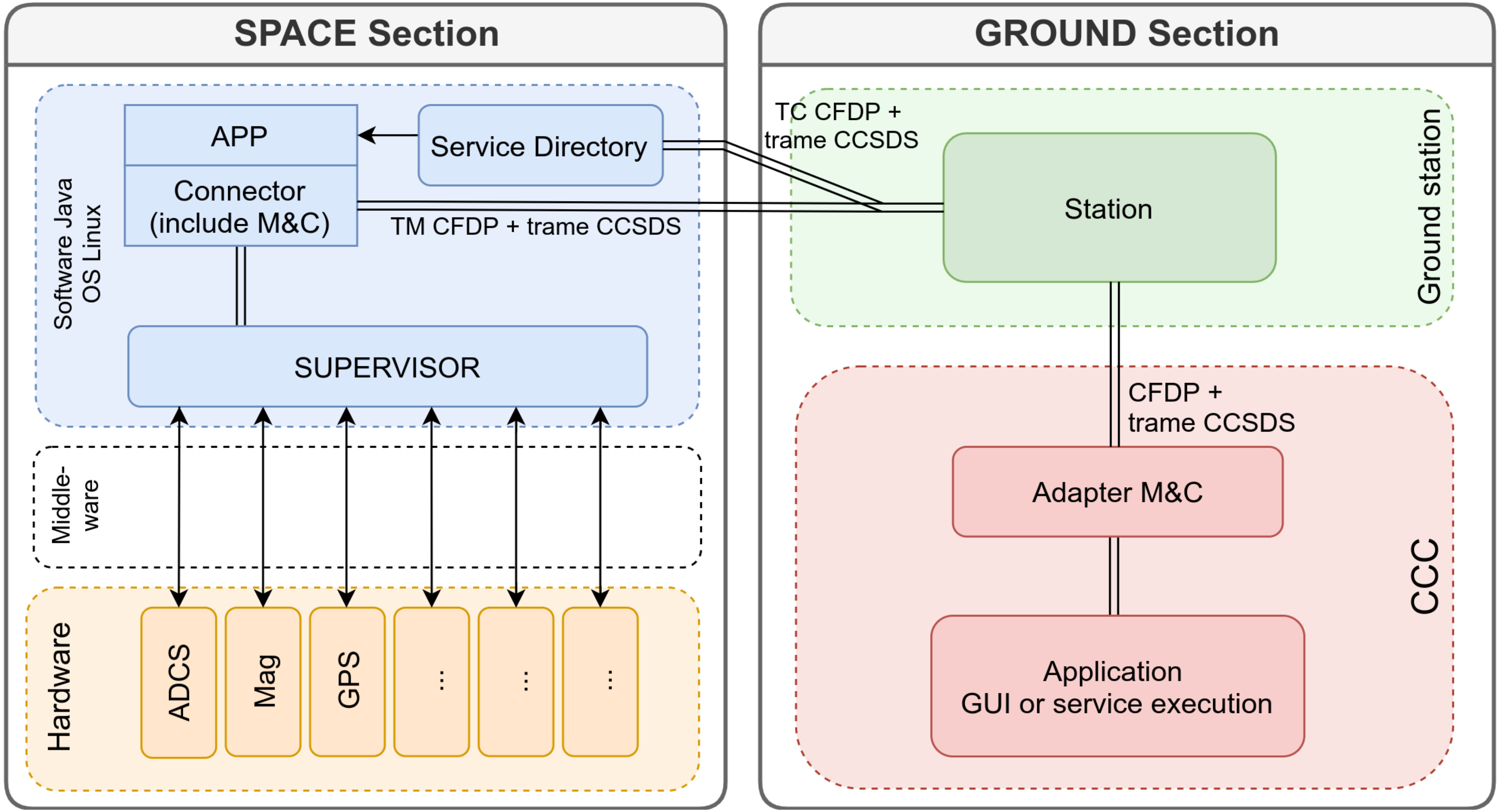
OPSSAT architecture:



OPSSAT ops architecture:



CCSDS MO layers: