AGU 2014 Poster G13A-0502

Which Orbit for the GRASP Mission ?

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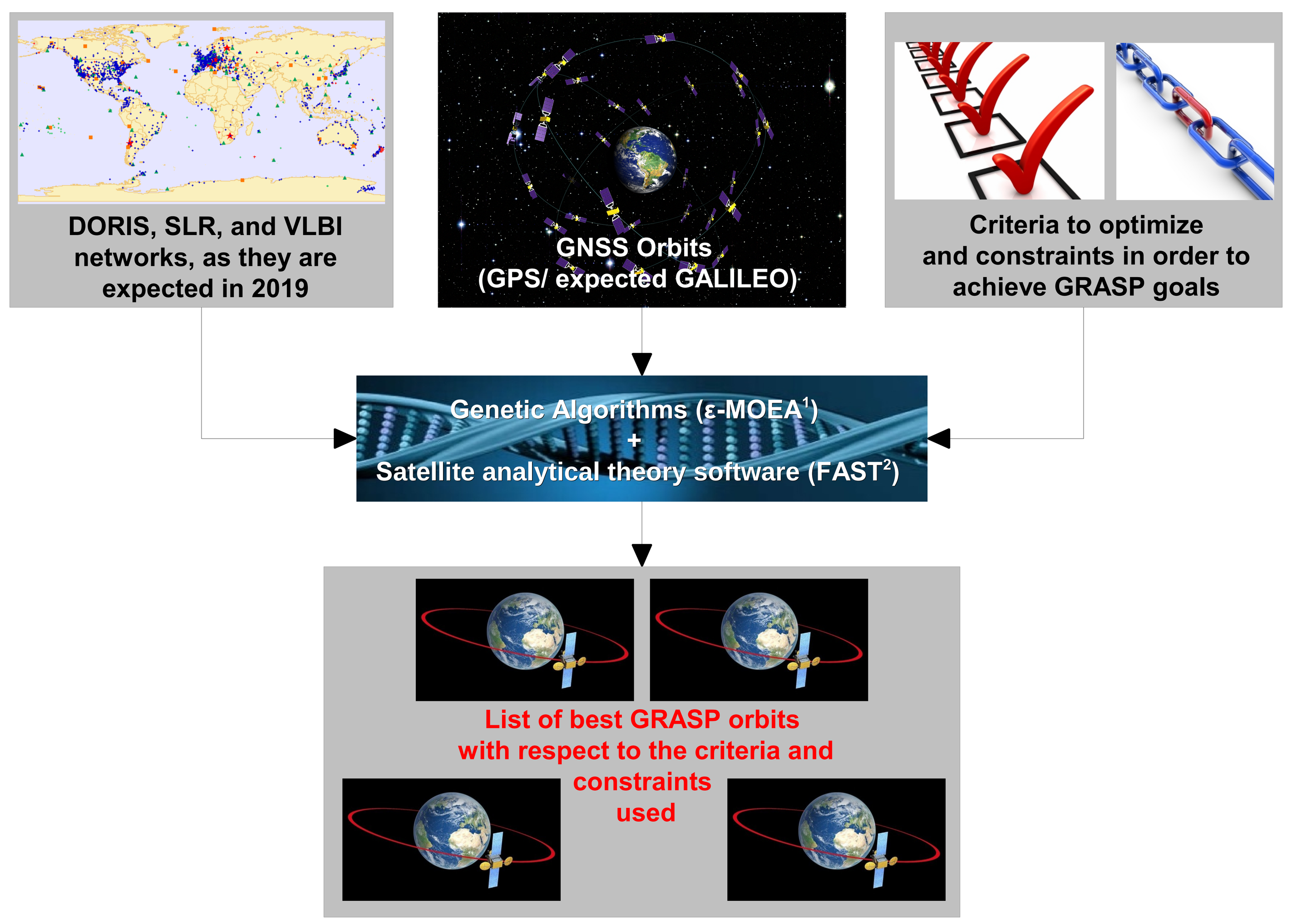
Overview — A

The Geodetic Reference Antenna in Space (GRASP) mission was first proposed in 2011 by JPL in response to the NASA NNH11ZDA012O call for Earth Venture-2 missions. Recently, considering the recommendation of the Prospective Scientific Seminar, CNES expresses its interest and the possibility to participate in a next new JPL proposal in response to the 2015 NASA's Earth Venture-mission call of opportunity (class B mission) .

GRASP is a spacecraft system designed to build an enduring and stable Terrestrial Reference Frame (TRF) for accurately measuring and understanding changes in sea level, ice sheets and other elements of the dynamic Earth system. These objectives set the 1 mm accuracy and 0.1 mm/year stability (GGOS, Meeting the Requirements of a Global Geodetic Observing System on a Changing Planet in 2020, Plag and Pearlman, 2009) as the goals for the TRF realization; goals which are an order of magnitude more accurate than the current performance of the TRF. For that, GRASP will carry very precise sensor systems for all the key geodetic techniques used to define and monitor the TRF: a Global Navigation Satellite Systems (GNSS) receiver, a Satellite Laser Ranging (SLR) retroreflector, a Doppler Orbitography and Radio-positioning Integrated by Satellite (DORIS) receiver, and a novel Very Large Baseline Interferometry (VLBI) beacon.

To reach mission goals, the first step is to determine the optimal orbit of this satellite. In this study, we present an original approach for determining such orbits, using evolutionary algorithms. The method allows us to optimize orbits according to specific criteria such as the visibility of the satellite from ground stations and GNSS satellites.

Method — B



Criteria used :

1. Maximize the period of visibility of GRASP by at least one station of each geodetic technique (DORIS/SLR/VLBI)[A].

2. Reduce the radiation dose received by GRASP.

3. Maximize the number of GNSS passes with a duration greater than 15 minutes (linked to the ambiguity fixation of GRASP GPS measurements).

[A]As this criteria favor upper altitude orbits, it maximizes as well the common VLBI visibility of GRASP.

Constraints used :

1. Visibility of GNSS antennas at a greater boresight angle than Jason-2 (linked to the GNSS antenna calibration with GRASP).

2. For each station, mean number of passes per day ≥ 3.

3. Common visibility of four GNSS satellite ≥ 90 % of the time.

4. GRASP passes per day over a NEN[B] station ≥ 2.

[B]NEN = NASA's Near Earth Network

Computations — C

Four preliminary orbit scenarios are currently proposed by CNES and NASA team for GRASP orbit :

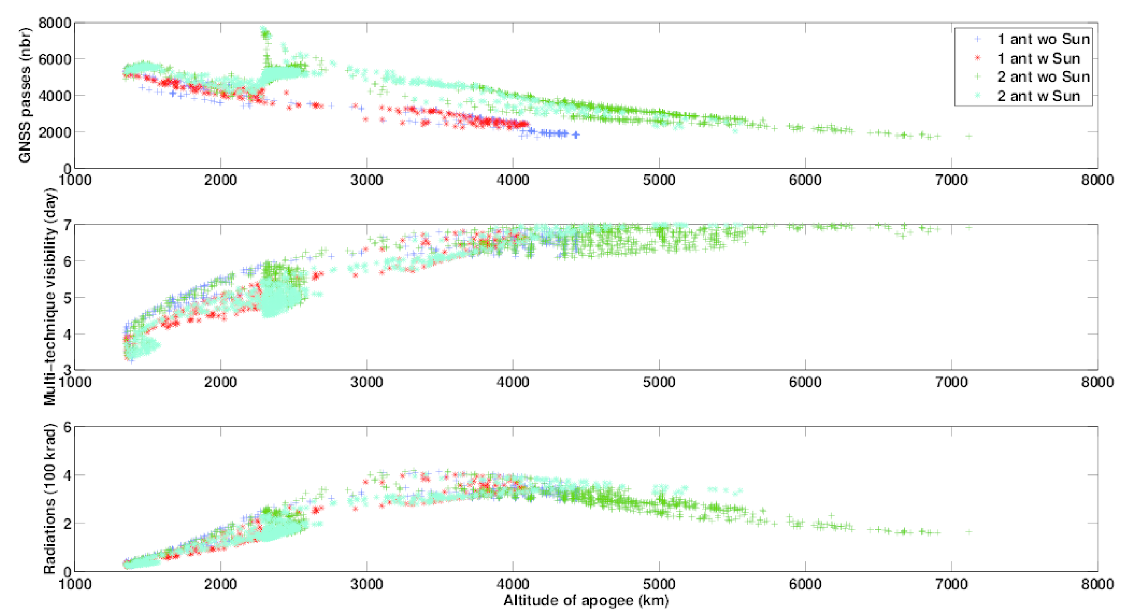
- **Scenario 1 : Sun-synchronous orbit 850x1350 km (a=7478.137 km, e=0.0033431, I=99.9°).** (1350 km)
- **Scenario 2 : Sun-synchronous circular orbit 1400 km (a=7778.137 km, I=101.4°).** (1400 km)
- **Scenario 3 : Sun-synchronous circular orbit 2000 km (a=8378.137 km, I=104.9°).** (2000 km)
- **Scenario 4 : Circular orbit 6000 km with medium inclination (a=12378.137 km, I=70°).** (6000 km)

To study the possible interest of a higher altitude for GRASP satellite (~ 6000 km), we computed a case with only one GNSS antenna on-board and a case with two antennas, one zenith oriented and one nadir oriented. For each of these two cases, we applied or not a sun-synchronism condition. We have thus computed four cases, via our genetic algorithm approach :

- **1_ANT_WO_SUN : 1 GNSS antenna on-board, without sun-synchronism condition.**
- **1_ANT_W_SUN : 1 GNSS antenna on-board, with sun-synchronism condition.**
- **2_ANT_WO_SUN : 2 GNSS antennas on-board, without sun-synchronism condition.**
- **2_ANT_W_SUN : 2 GNSS antennas on-board, with sun-synchronism condition.**

Results — D

Solutions of the Pareto front provided by the stochastic algorithms for each case :



- Interest of 2 GNSS antennas for 2500 km or higher altitude.
- With altitude higher than 4000-5000 km, the number of long GNSS passes (≥ 15 min) is low, even with the two antennas.
- To receive the same order of radiations than an orbit at lower altitude (≤ 2000 km), the apogee must be greater than 6000 km.

Optimized orbit configuration :

- If the total radiation dose is limited to the level of radiations received by a satellite at 2000 km :

	1 GNSS antenna	2 GNSS antennas
Sun-synchronism	1741 km — Altitude 1723 x 1741 km, Eccentricity 0.001082, Inclination 103.27°	2388 km — Altitude 1687 x 2388 km, Eccentricity 0.041615, Inclination 105.09°
No sun-synchronism	1760 km — Altitude 1715 x 1760 km, Eccentricity 0.002749, Inclination 120.00°	2071 km — Altitude 1449 x 2071 km, Eccentricity 0.038217, Inclination 119.98°

- If we consider no radiation problem with a sufficient shielding thickness :

	Sun-synchronism	No sun-synchronism
2 GNSS antennas	3623 km — Altitude 2277 x 3623 km, Eccentricity 0.072177, Inclination 111.75°	3135 km — Altitude 2352 x 3135 km, Eccentricity 0.042916, Inclination 60.64°

Results — D

Four CNES/NASA scenarios :

	1350 km	1400 km	2000 km	6000 km
GNSS Antennas	1	1	1	2
GNSS passes ≥ 15 min	5370	4996	3961	2072
Multi-tech visibility[3] (days)	3.34	4.01	5.05	6.98
Radiations[4] (krad)	22.674	43.640	156.698	192.278
VLBI mutual visibility[5] (days)	1.12	1.83	3.18	6.80

In green :

- "GNSS passes ≥ 15 min" ≥ 4000
- "Multi-tech. Visibility" ≥ 4.66 days
- "Radiations" ≤ max radiation dose at 2000 km.
- "VLBI mutual visibility" ≥ 4.66 days

In red :

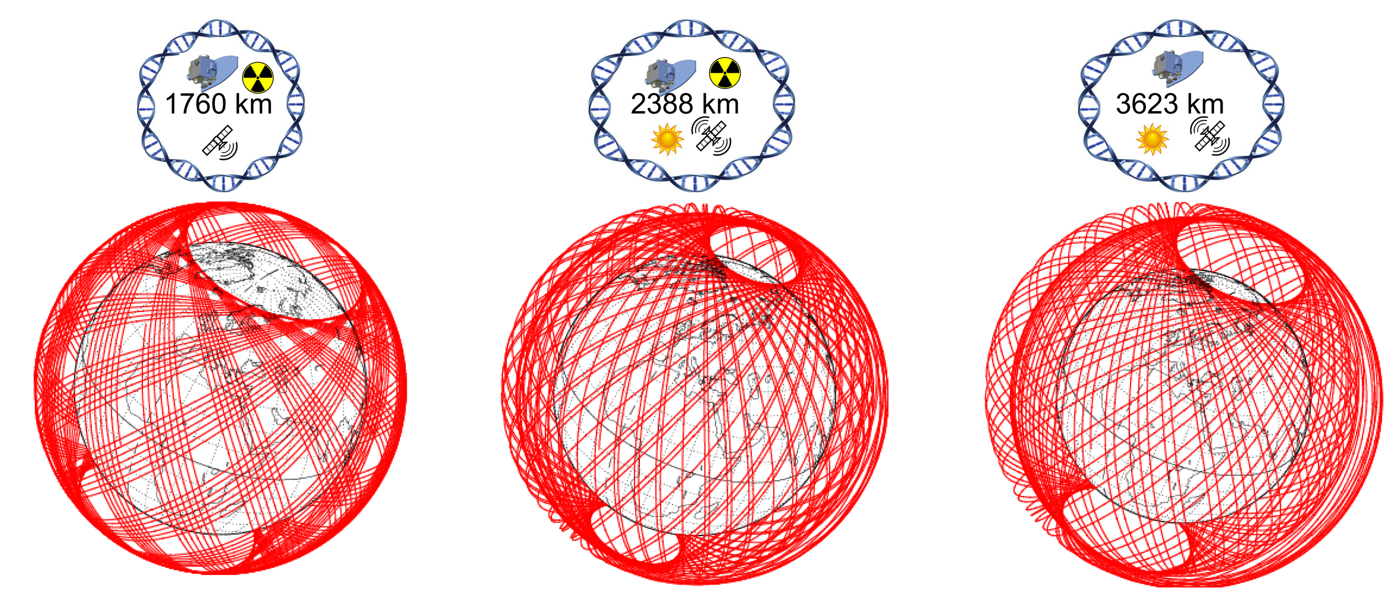
- "GNSS passes ≥ 15 min" < 4000
- "Multi-tech. Visibility" ≤ 2.33 days
- "Radiations" > max radiation dose at 2000 km.
- "VLBI mutual visibility" ≤ 2.33 days

Six optimized orbit configurations :

	1760 km	1741 km	2071 km	2388 km	3135 km	3623 km
GNSS Antennas	1	1	2	2	2	2
GNSS passes ≥ 15 min	4506	4371	5067	5073	4912	4676
Multi-tech visibility[3] (days)	5.08	4.64	5.09	5.08	6.38	6.21
Radiations[4] (krad)	113.016	96.734	131.595	175.420	348.680	317.940
VLBI mutual visibility[5] (days)	2.64	2.58	2.68	3.25	4.48	4.77

[3]Multi-tech. Visibility : Common visibility of at least one station per geodetic technique, over 7 days.
[4]Radiations : Radiations computed over 5 years, at the center of a sphere, with 1g/cm^2 Al shielding thickness, using AE8Max/AP8Min NASA models.
[5]VLBI mutual visibility : Common visibility of at least two VLBI stations with at least 2500 km baseline, over 7 days.

Example of orbits proposed by the genetic algorithms :



Acknowledgments — E

We are grateful to M. Capderou (LMD), A. Auriol (CNES), A. Laurens (CNES), G. Rolland (CNES), and NASA JPL team for fruitful discussions, and CNES for financial support.

Bibliography — F

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