



ON-BOARD NAVIGATION FOR LEO, MEO, GEO... AND BEYOND

INTERNATIONAL NAVIGATION CONFERENCE 2019, EDINBURGH

20TH NOVEMBER 2019

Remi Challamel, Thales Alenia Space UK Limited
Remi.challamel@thalesaleniaspace.com



Date: 20th nov. 2019
Ref: TAS-UK-2019-INC-OBNAV-01
Template: 83230347-DOC-TAS-EN-006

PROPRIETARY INFORMATION
This document is not to be reproduced, modified, adapted, published, translated in any material form in whole or in part nor disclosed to any third party without the prior written permission of Thales Alenia Space UK Ltd.
© 2019 Thales Alenia Space UK Ltd

THALES ALENIA SPACE OPEN



AGENDA

- 1 Introduction
- 2 Few missions considered
- 3 Requirements
- 4 Sensors
- 5 Performances - accuracy, autonomy,..
- 6 Next steps

Date: 20th nov. 2019
Ref: TAS-UK-2019-INC-OBNAV-01
Template: 83230347-DOC-TAS-EN-006

PROPRIETARY INFORMATION
This document is not to be reproduced, modified, adapted, published, translated in any material form in whole or in part nor disclosed to any third party without the prior written permission of Thales Alenia Space UK Ltd.
© 2019 Thales Alenia Space UK Ltd

THALES ALENIA SPACE OPEN

ThalesAlenia
Space
a Thales / Leonardo company



INTRODUCTION

Date: 20th nov. 2019
Ref: TAS-UK-2019-INC-OBNAV-01
Template: 83230347-DOC-TAS-EN-006

PROPRIETARY INFORMATION
This document is not to be reproduced, modified, adapted, published, translated in any material form in whole or in part nor disclosed to any third party without the prior written permission of Thales Alenia Space UK Ltd.
© 2019 Thales Alenia Space UK Ltd

THALES ALENIA SPACE OPEN

ThalesAlenia
Space
Thales / Leonardo company

INTRODUCTION



- Which missions?
- Which requirements ? More autonomy ?
- Sensors
- Performances
- Next Steps

Date: 20th nov. 2019
Ref: TAS-UK-2019-INC-OBNAV-01
Template: 83230347-DOC-TAS-EN-006

PROPRIETARY INFORMATION
This document is not to be reproduced, modified, adapted, published, translated in any material form in whole or in part nor disclosed to any third party without the prior written permission of Thales Alenia Space UK Ltd.
© 2019 Thales Alenia Space UK Ltd

THALES ALENIA SPACE OPEN

ThalesAlenia
Space
Thales / Leonardo company

CREDIT

/// Most of the results come from the following project:



/ ESA FUNDED NAVISP-EL1-025: MULTI-SENSOR, MULTI-SYSTEM FOR SPACE PNT APPLICATIONS, “MUSE4PNT”, SUPPORTED BY UKSA : LED BY TAS-UK WITH TAS-F, SINTEF, ASTROSCALE. PROJECT STARTED IN OCTOBER 2019,



/ ESA FUNDED GSTP STUDY “SIREUS NG10”, SUPPORTED BY UKSA: DEVELOPMENT OF A EQM OF A LOW COST, MEDIUM PERFORMANCE INERTIAL SENSOR, LED BY TAS-UK,

/ EU FUNDED H2020 “I3DS”: INTEGRATED 3D SENSORS. “SMART SENSORS FOR SMART MISSIONS” IS AN H2020 EUROPEAN PROJECT LED BY TASF PART OF THE CURRENT H2020 SRC ON SPACE ROBOTICS AS OG4. IN THIS PROJECT, A GENERIC SENSOR SUITE FOR RENDEZVOUS MISSION ARE DEFINED, DEVELOPED AND TESTED IN TASF FACILITIES. PARTNERS OF THE CONSORTIUM ARE: TASF (COORDINATOR), PIAP, TASUK, TAS-E, TASI, SINTEF, COSINE, TERMA, UNIVERSITY OF CRANFIELD, HERTZ SYSTEMS. MULTIPLE VISION SYSTEMS HAVE BEING TESTED WITHIN TASF FACILITIES IN Q4 2018 INCLUDING MSD CAMERAS AND LIDARS. THE I3DS PROJECT HAS RECEIVED FUNDING FROM THE EUROPEAN UNION’S HORIZON 2020 REASEARCH AND INNOVATION PROGRAMME UNDER GRANT AGREEMENT NO 730118



/ EU FUNDED H2020 EROSS: THIS ACTIVITY CONTINUE THE I3DS EFFORT WITH A FULL SPACETUG DESIGN AND KEY GNC ALGORITHMS AND UNITS TESTING INCLUDING A ROBOTIC ARM, A REFUELLING INTERFACE AND MANY SENSORS. PARTNERS OF THE CONSORTIUM ARE: TASF (COORDINATOR), GMV, NTUA, PIAP, SENER, SINTEF, SODERN, SPACEAPPS, TASI, TASUK AND UOC. EROSS PROJECT HAS RECEIVED FUNDING FROM THE EUROPEAN UNION’S HORIZON 2020 REASEARCH AND INNOVATION PROGRAMME UNDER GRANT AGREEMENT NO NO 821904.



Date: 20th nov. 2019
Ref: TAS-UK-2019-INC-OBNAV-01
Template: 83230347-DOC-TAS-EN-006

PROPRIETARY INFORMATION

This document is not to be reproduced, modified, adapted, published, translated in any material form in whole or in part nor disclosed to any third party without the prior written permission of Thales Alenia Space UK Ltd.
© 2019 Thales Alenia Space UK Ltd

THALES ALENIA SPACE OPEN

ThalesAlenia
Space
Thales / Leonardo company



FEW MISSIONS CONSIDERED

Date: 20th nov. 2019

Ref: TAS-UK-2019-INC-OBNAV-01

Template: 83230347-DOC-TAS-EN-006

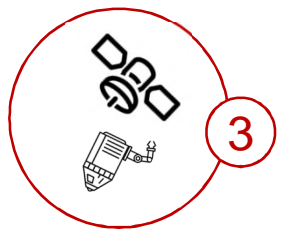
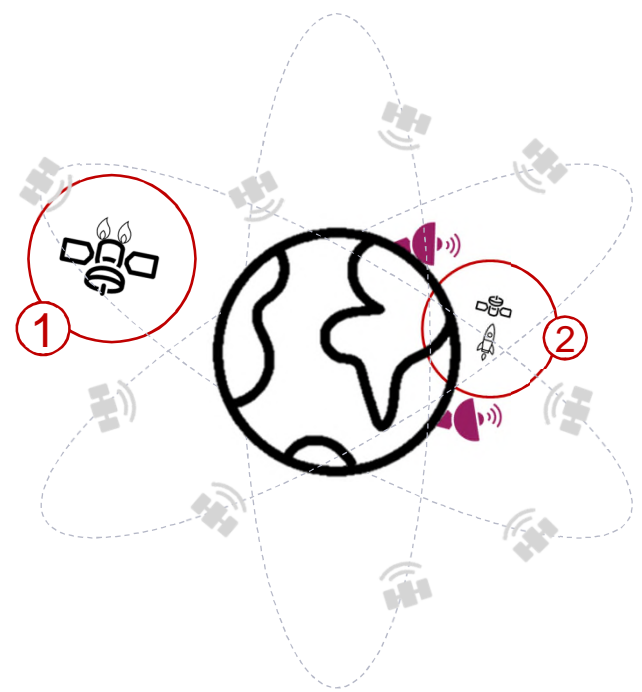
PROPRIETARY INFORMATION

This document is not to be reproduced, modified, adapted, published, translated in any material form in whole or in part nor disclosed to any third party without the prior written permission of Thales Alenia Space UK Ltd.
© 2019 Thales Alenia Space UK Ltd

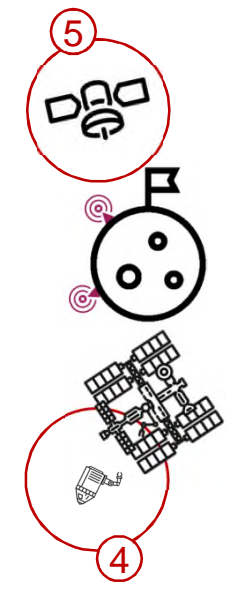
THALES ALENIA SPACE OPEN

ThalesAlenia
Space
Thales / Leonardo company

MISSIONS



#	Mission
1	Autonomous orbit raising & station keeping
2	Post separation optimization
3	In-orbit servicing (LEO, GEO)
4	In-orbit servicing (lunar)
5	Lunar vicinities navigation



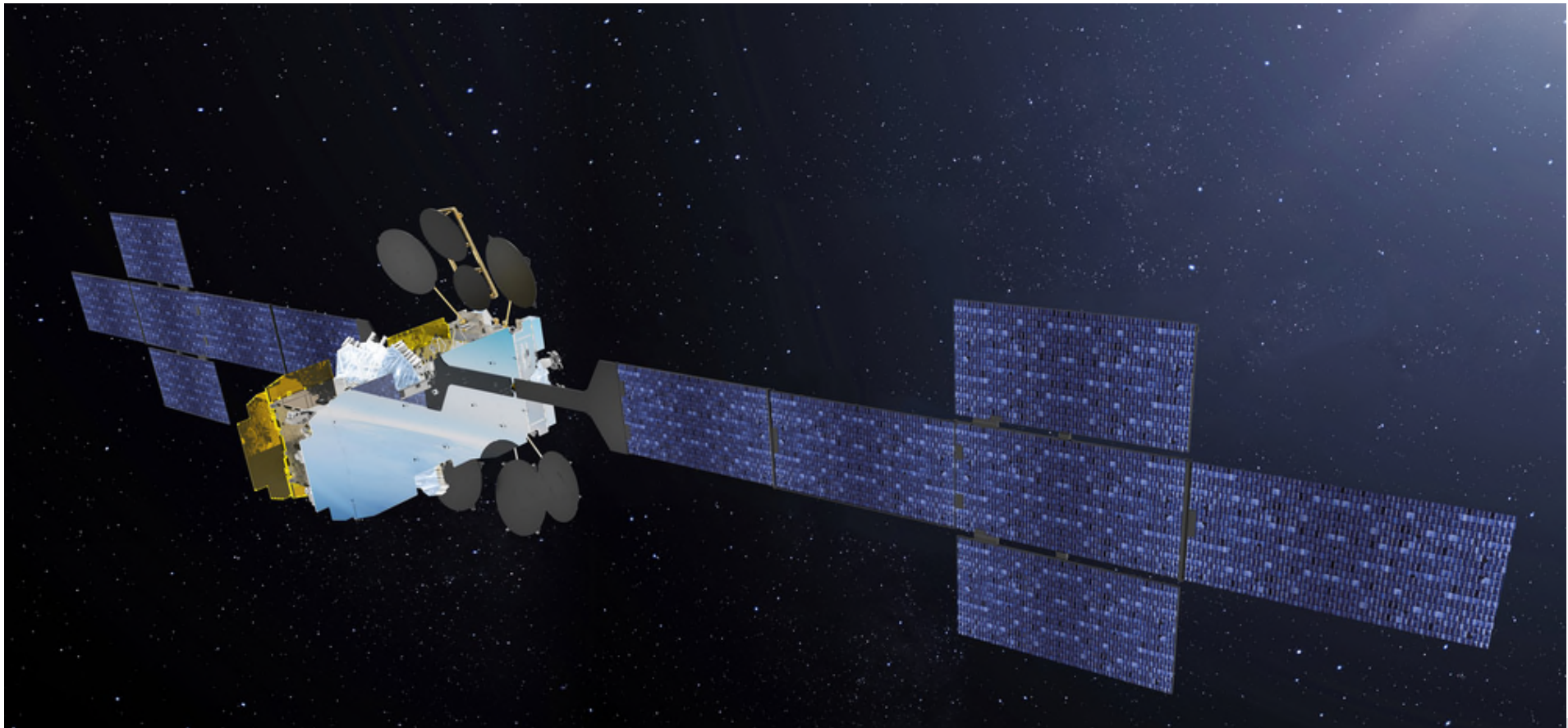
Date: 20th nov. 2019
 Ref: TAS-UK-2019-INC-OBNAV-01
 Template: 83230347-DOC-TAS-EN-006

PROPRIETARY INFORMATION
 This document is not to be reproduced, modified, adapted, published, translated in any material form in whole or in part nor disclosed to any third party without the prior written permission of Thales Alenia Space UK Ltd.
 © 2019 Thales Alenia Space UK Ltd

THALES ALENIA SPACE OPEN



AUTONOMOUS ORBIT RAISING & STATION KEEPING



Date: 20th nov. 2019
Ref: TAS-UK-2019-INC-OBNAV-01
Template: 83230347-DOC-TAS-EN-006

PROPRIETARY INFORMATION
This document is not to be reproduced, modified, adapted, published, translated in any material form in whole or in part nor disclosed to any third party without the prior written permission of Thales Alenia Space UK Ltd.
© 2019 Thales Alenia Space UK Ltd

THALES ALENIA SPACE OPEN

ThalesAlenia
Space
a Thales / Leonardo company

AUTONOMOUS ORBIT RAISING & STATION KEEPING

Electric Propulsion for Satellites

Electric propulsion allows the satellite to **carry larger payloads** as it doesn't carry chemical propellant which takes up more room

Orbiting directly over the Equator, the satellite will travel at **3km per second (or 6,700mph)** at an altitude of nearly **36,000km** above the Earth

Electrical energy is collected from the Sun by the satellite's solar panels and converted into thrust by the acceleration of Xenon gas from an **electric thruster**

The gas can reach speeds in excess of **42,000 mph... or 19km per second** which means the system is very economical in fuel use compared to traditional chemical propulsion systems

Date: 20th nov. 2019
Ref: TAS-UK-2019-INC-OBNAV-01
Template: 83230347-DOC-TAS-EN-006

PROPRIETARY INFORMATION
This document is not to be reproduced, modified, adapted, published, translated in any material form in whole or in part nor disclosed to any third party without the prior written permission of Thales Alenia Space UK Ltd.
© 2019 Thales Alenia Space UK Ltd

THALES ALENIA SPACE OPEN

ThalesAlenia
Space
Thales / Leonardo company

AUTONOMOUS ORBIT RAISING & STATION KEEPING – Electric Propulsion

Propulsion – Delivery of the first All-Electric Propulsion module designed and built in the UK



Celebrating Collaboration!

BB4A Consent to Ship Review 13 December
ESA, Eutelsat, TAS-F, TAS-UK & TUKL



BB4A XPS Module Shipment Belfast 17 December 2018

Date: 20th nov. 2019
Ref: TAS-UK-2019-INC-OBNAV-01
Template: 83230347-DOC-TAS-EN-006

PROPRIETARY INFORMATION
This document is not to be reproduced, modified, adapted, published, translated in any material form in whole or in part nor disclosed to any third party without the prior written permission of Thales Alenia Space UK Ltd.
© 2019 Thales Alenia Space UK Ltd

THALES ALENIA SPACE OPEN

ThalesAlenia
Space
a Thales / Leonardo company

AUTONOMOUS ORBIT RAISING & STATION KEEPING - CONSTELLATION



Date: 20th nov. 2019
Ref: TAS-UK-2019-INC-OBNAV-01
Template: 83230347-DOC-TAS-EN-006

PROPRIETARY INFORMATION
This document is not to be reproduced, modified, adapted, published, translated in any material form in whole or in part nor disclosed to any third party without the prior written permission of Thales Alenia Space UK Ltd.
© 2019 Thales Alenia Space UK Ltd

THALES ALENIA SPACE OPEN

ThalesAlenia
Space
a Thales / Leonardo company

POST SEPARATION OPTIMIZATION



Date: 20th nov. 2019
Ref: TAS-UK-2019-INC-OBNAV-01
Template: 83230347-DOC-TAS-EN-006

PROPRIETARY INFORMATION
This document is not to be reproduced, modified, adapted, published, translated in any material form in whole or in part nor disclosed to any third party without the prior written permission of Thales Alenia Space UK Ltd.
© 2019 Thales Alenia Space UK Ltd

THALES ALENIA SPACE OPEN

ThalesAlenia
Space
a Thales / Leonardo company

A WINDOW
ON THE EARTH
CUPOLA



IN-ORBIT SERVICES (LEO, GEO)

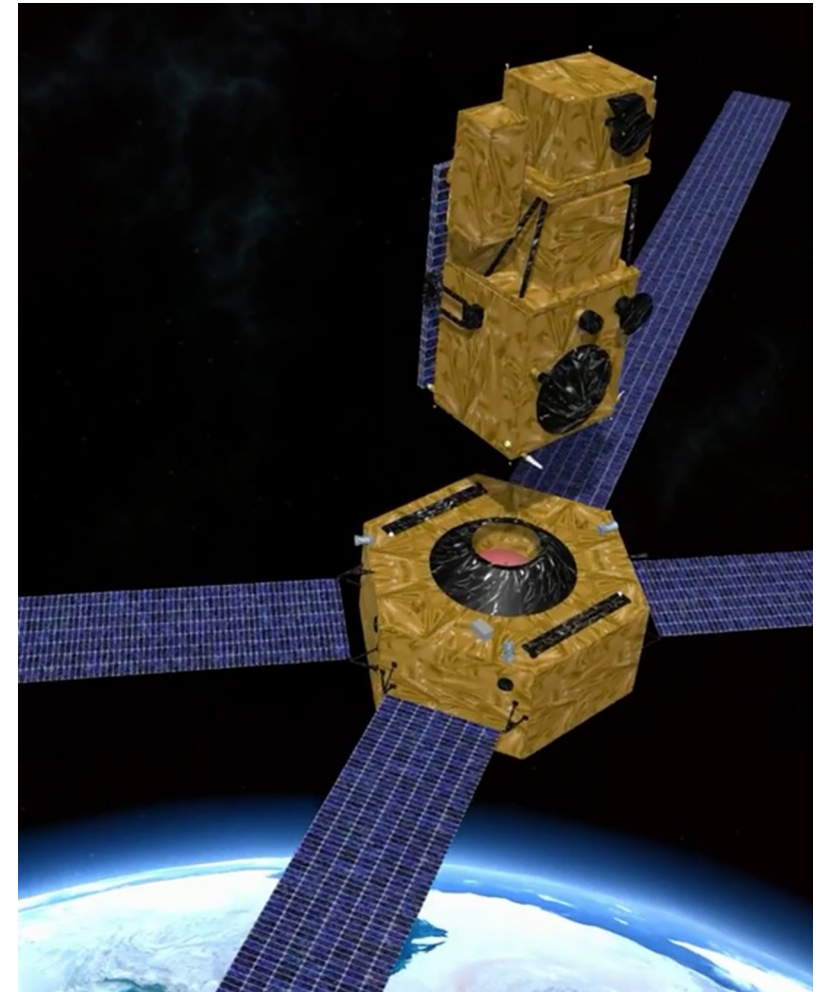
/// A new type of vehicle to make space more sustainable and to provide enhanced satellite services

TODAY

Satellites in orbit cannot currently be refueled, maintained or upgraded, so their capabilities are static and their service life is limited.

TOMORROW

In-orbit space servicers will change everything, bringing a range of new possibilities: life extension, maintenance, relocation, payload upgrade, debris clean-up, base-building...



Date: 20th nov. 2019
Ref: TAS-UK-2019-INC-OBNAV-01
Template: 83230347-DOC-TAS-EN-006

PROPRIETARY INFORMATION
This document is not to be reproduced, modified, adapted, published, translated in any material form in whole or in part nor disclosed to any third party without the prior written permission of Thales Alenia Space UK Ltd.
© 2019 Thales Alenia Space UK Ltd

THALES ALENIA SPACE OPEN

ThalesAlenia
Space
Thales / Leonardo company

IN-ORBIT SERVICING (LUNAR)

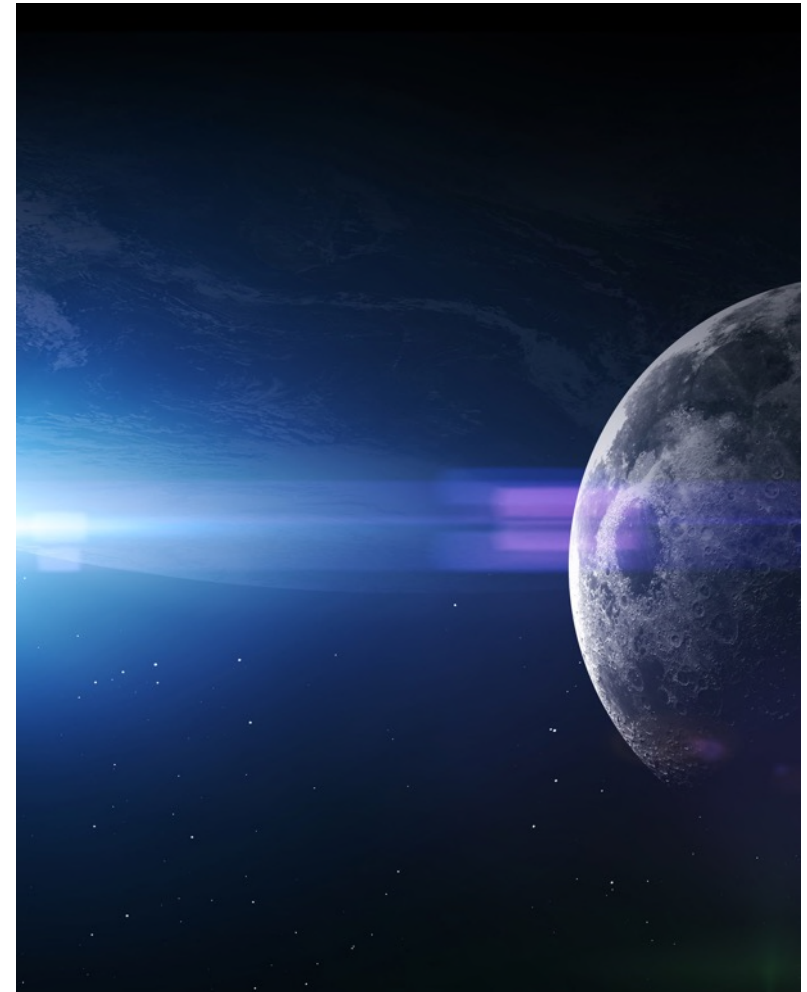
/// The Lunar Orbital Platform-Gateway (LOP-G) will orbit the moon as a comms hub, science lab, short-stay habitat & equipment storage zone

TODAY

LOP-G will be a test-base for the environmental systems that will be needed to keep astronauts alive on long voyages to deep space.

TOMORROW

It could also be a launch point for future missions to the moon, to Mars or to rendezvous with asteroids.



Date: 20th nov. 2019
Ref: TAS-UK-2019-INC-OBNAV-01
Template: 83230347-DOC-TAS-EN-006

PROPRIETARY INFORMATION
This document is not to be reproduced, modified, adapted, published, translated in any material form in whole or in part nor disclosed to any third party without the prior written permission of Thales Alenia Space UK Ltd.
© 2019 Thales Alenia Space UK Ltd

THALES ALENIA SPACE OPEN

ThalesAlenia
Space
a Thales / Leonardo company

LUNAR VICINITIES NAVIGATION

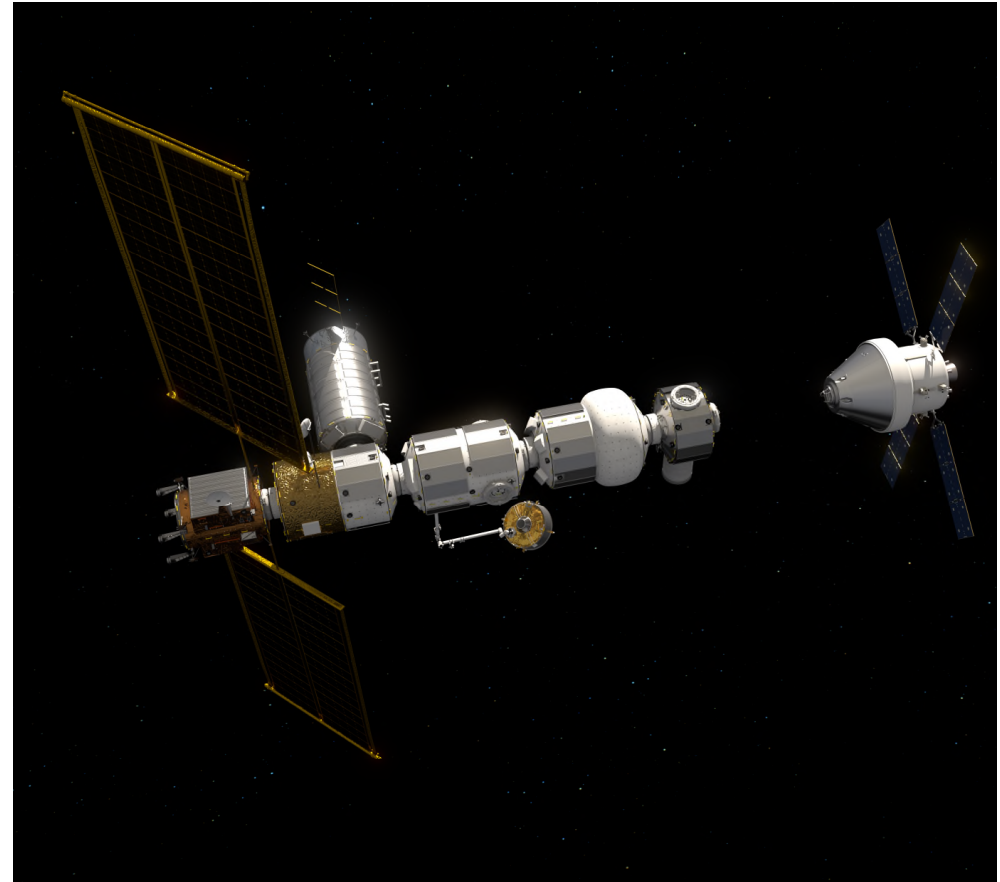
/// HERACLES: ESA is working with the Canadian and Japanese space agencies to prepare the Heracles robotic mission to the Moon in the mid-to-late-2020s. Using the Gateway as a halfway point, a robotic rover will scout the terrain in preparation for the future arrival of astronauts, and deliver lunar samples to Earth.

ON THE MOON

A small lander with a rover inside weighing around 1800 kg in total will land and be monitored by astronauts from the space gateway. An ascent module will take off from the surface and return to the gateway with samples taken by the rover..

LUNAR IOS

When the ascent module carrying the sample container arrives, the Gateway's robotic arm will capture and berth it with the outpost's airlock for unpacking and transfer of the container to Orion and subsequent flight to Earth with returning astronaut



Date: 20th nov. 2019
Ref: TAS-UK-2019-INC-OBNAV-01
Template: 83230347-DOC-TAS-EN-006

PROPRIETARY INFORMATION
This document is not to be reproduced, modified, adapted, published, translated in any material form in whole or in part nor disclosed to any third party without the prior written permission of Thales Alenia Space UK Ltd.
© 2019 Thales Alenia Space UK Ltd

THALES ALENIA SPACE OPEN

ThalesAlenia
Space
Thales / Leonardo company



REQUIREMENTS

Date: 20th nov. 2019
Ref: TAS-UK-2019-INC-OBNAV-01
Template: 83230347-DOC-TAS-EN-006

PROPRIETARY INFORMATION
This document is not to be reproduced, modified, adapted, published, translated in any material form in whole or in part nor disclosed to any third party without the prior written permission of Thales Alenia Space UK Ltd.
© 2019 Thales Alenia Space UK Ltd

THALES ALENIA SPACE OPEN

ThalesAlenia
Space
Thales / Leonardo company

REQUIREMENTS



- /// Accuracy: The navigation system shall be able to provide absolute and relative position and velocity with a precision sufficient to allow the mission.
- /// Autonomy: The navigation system shall operate without intervention from the ground. If ground intervention is required it should be made as little as possible and ways to decrease it even further should be suggested.
- /// Compatibility with flight computers: Flight computers typically have limited computing power and require highly optimized and computer-efficient algorithms.
- /// Robustness: The navigation system shall be able to work in a wide variety of environments which means varying light conditions, varying atmospheric conditions, different spacecraft altitudes, different viewing angles and with a wide range of surface topography, albedo and texture.
- /// Integration: the level of integration in the avionics is an important driver to the performance of the overall system. Data processing performed in the AOCS may offer more possibilities to the avionics design team and enhance the in-flight configurability options.
- /// Mass and cost: especially for commercial and constellation missions, it is the main driver for the selection of systems. Solutions that can merge with existing systems is the new trend for commercial products.

Date: 20th nov. 2019
Ref: TAS-UK-2019-INC-OBNAV-01
Template: 83230347-DOC-TAS-EN-006

PROPRIETARY INFORMATION
This document is not to be reproduced, modified, adapted, published, translated in any material form in whole or in part nor disclosed to any third party without the prior written permission of Thales Alenia Space UK Ltd.
© 2019 Thales Alenia Space UK Ltd

THALES ALENIA SPACE OPEN

ThalesAlenia
Space
Thales / Leonardo company

AUTONOMY



/// Higher level of autonomy is required for several different reasons :

/ TECHNOLOGY EVOLUTION (ELECTRICAL PROPULSION): LARGE GAIN OF MASS BUT ORBIT RAISING MAY TAKE SEVERAL MONTHS AND IS BETTER MANAGED THROUGH AUTONOMOUS NAVIGATION AND AUTONOMOUS ORBIT MANOEUVRES COMPUTED ON-BOARD

/ NEW MARKET (LARGE CONSTELLATIONS): SEPARATION SEQUENCES, ORBIT INSERTION AND CONTROL MANOEUVRES

/ CLEAN SPACE/SERVICING

/ INCREASE RELIABILITY OF INTERPLANETARY MISSIONS (IN NOT WELL KNOWN ENVIRONMENT): CAPACITY OF CHANGING MISSION PARAMETERS IN REAL TIME IN ORDER TO MAKE THE MISSION SAFER OR WITH A BETTER ACCURACY THANKS TO SHORTER DECISION LOOPS

Date: 20th nov. 2019
Ref: TAS-UK-2019-INC-OBNAV-01
Template: 83230347-DOC-TAS-EN-006

PROPRIETARY INFORMATION
This document is not to be reproduced, modified, adapted, published, translated in any material form in whole or in part nor disclosed to any third party without the prior written permission of Thales Alenia Space UK Ltd.
© 2019 Thales Alenia Space UK Ltd

THALES ALENIA SPACE OPEN

ThalesAlenia
Space
Thales / Leonardo company

AUTONOMY



/// Higher level of autonomy is required for several different reasons (cont'd)

/ ADD AUTONOMOUS ON-BOARD CAPABILITY TO DEFINE THE INSTRUMENT ACQUISITION PLAN AND/OR THE PDHT DOWNLOAD PLAN (TYPICALLY FOR EARTH OBSERVATION SATELLITES) SUCH AS TO MAXIMIZE THE OBSERVATION OF AREAS OF INTEREST

/ PREDICTIVE MAINTENANCE & ADVANCED FDIR (FAILURE DETECTION ISOLATION AND RECOVERY)

/ MORE ROBUSTNESS & RESILIENCE AGAINST GROUND SEGMENT FAILURE OR DAMAGE

Date: 20th nov. 2019
Ref: TAS-UK-2019-INC-OBNAV-01
Template: 83230347-DOC-TAS-EN-006

PROPRIETARY INFORMATION
This document is not to be reproduced, modified, adapted, published, translated in any material form in whole or in part nor disclosed to any third party without the prior written permission of Thales Alenia Space UK Ltd.
© 2019 Thales Alenia Space UK Ltd

THALES ALENIA SPACE OPEN

ThalesAlenia
Space
Thales / Leonardo company

AUTONOMY



/// From these needs the trends can be considered as follows :

- / AUTONOMOUS MANOEUVRING CAPABILITY FOR ALL S/C IN EARTH ORBIT: ORBIT DETERMINATION, PATH PLANNING, ADVANCED GNC**
- / USE OF SOME INSTRUMENTS DATA IN REAL TIME TO UPGRADE THE MISSION TIME-LINE WITHOUT GROUND INTERVENTION / AUTONOMOUS RDV, AUTONOMOUS LANDING & ROVER OPERATIONS**
- / WORK ON SATELLITE HKTM AND INTERNAL SATELLITE DATA (COMPLEMENTARY TO THE SDB) FOR A NEXT STEP OF FDIR CAPABILITIES**

Date: 20th nov. 2019
Ref: TAS-UK-2019-INC-OBNAV-01
Template: 83230347-DOC-TAS-EN-006

PROPRIETARY INFORMATION
This document is not to be reproduced, modified, adapted, published, translated in any material form in whole or in part nor disclosed to any third party without the prior written permission of Thales Alenia Space UK Ltd.
© 2019 Thales Alenia Space UK Ltd

THALES ALENIA SPACE OPEN

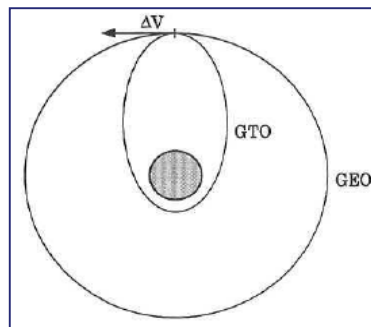
ThalesAlenia
Space
Thales / Leonardo company

AUTONOMOUS ORBIT RAISING & STATION KEEPING

GTO to GEO transfer principles with chemical propulsion :

Thrust = 400N

Isp = 320s (MON/MMH)

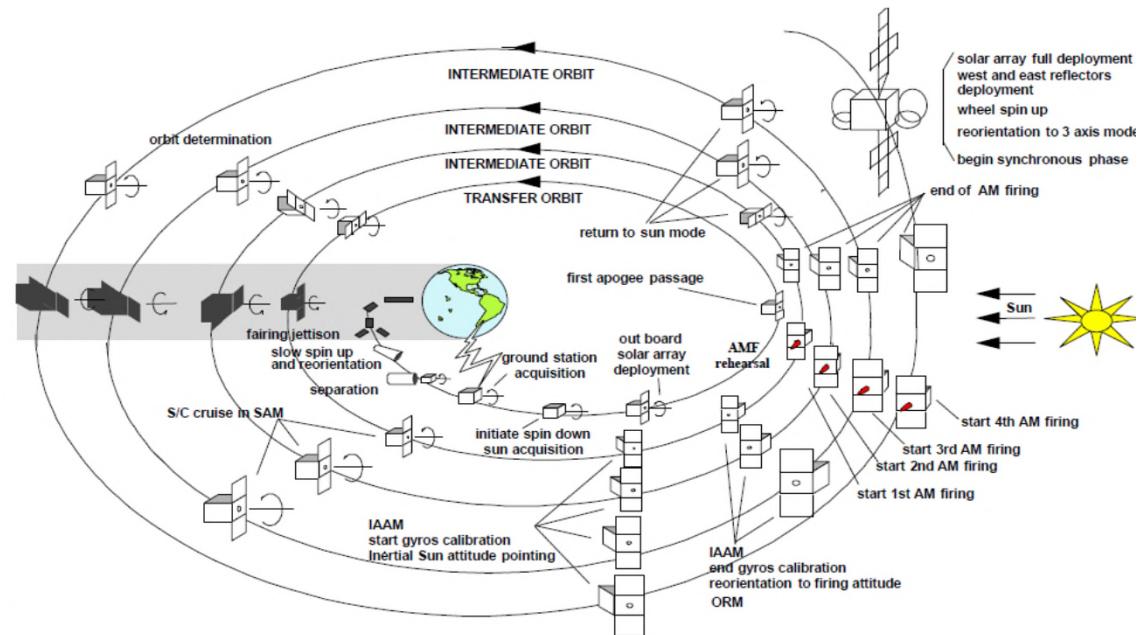


DV must be produced at apogee to increase perigee

Efficiency is directly linked to the DV spread (eff = 1)

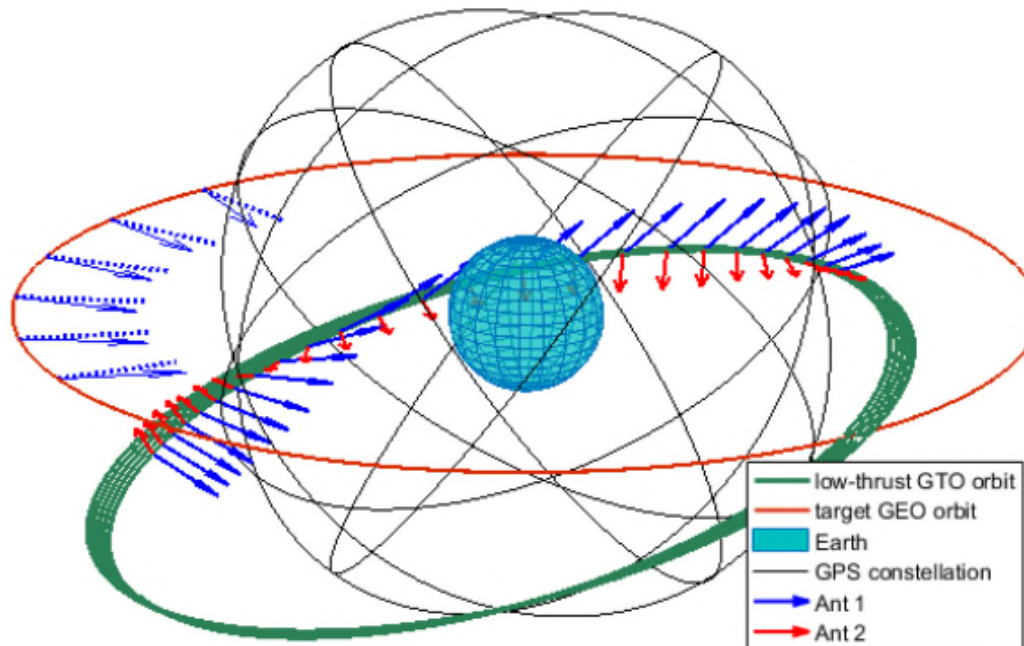
In 4 burns of 2h each, you produce DV to reach GEO

... but you need 2500-3000kg of propellant (MON/MMH)



AUTONOMOUS ORBIT RAISING & STATION KEEPING

Orbits and attitude in cartesian coordinates J2000



Ref: "AUTONOMOUS, LOW-COST GNSS POSITIONING AND TIMING FUNCTION UNDER ELECTRICAL PROPULSION TOWARD THE GEOSTATIONARY ORBIT: A NOVEL KALMAN FILTERING APPROACH"; Ferrario Alessandro, Zin Alberto, Zago Stefano, Piccolo Andrea, Pecchioni Cristina, Casotto Stefano, Bardella Massimo, NAVITEC 2018

Trajectories of Electric Propulsion orbit cases and example of RX antenna BoreSight orientation

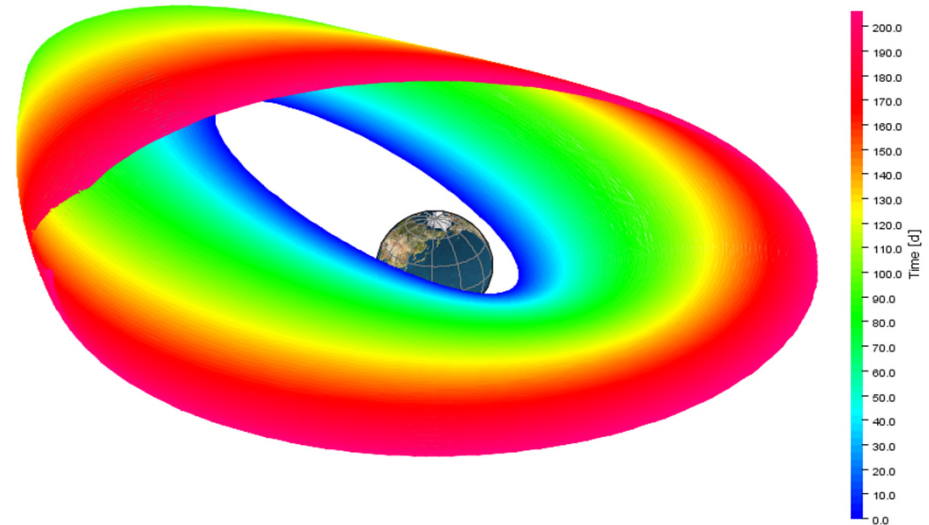
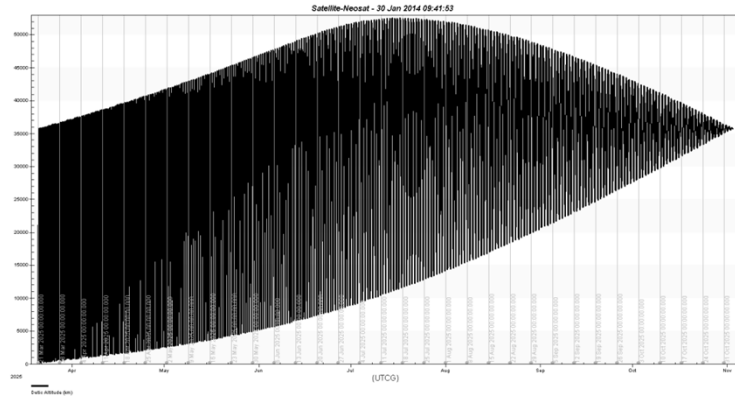
Date: 20th nov. 2019
Ref: TAS-UK-2019-INC-OBNAV-01
Template: 83230347-DOC-TAS-EN-006

PROPRIETARY INFORMATION
This document is not to be reproduced, modified, adapted, published, translated in any material form in whole or in part nor disclosed to any third party without the prior written permission of Thales Alenia Space UK Ltd.
© 2019 Thales Alenia Space UK Ltd

THALES ALENIA SPACE OPEN

ThalesAlenia
Space
Thales / Leonardo company

POST SEPARATION OPTIMIZATION



GTO (Geostationary Transfer Orbit) to GEO transfer principles with electric propulsion :

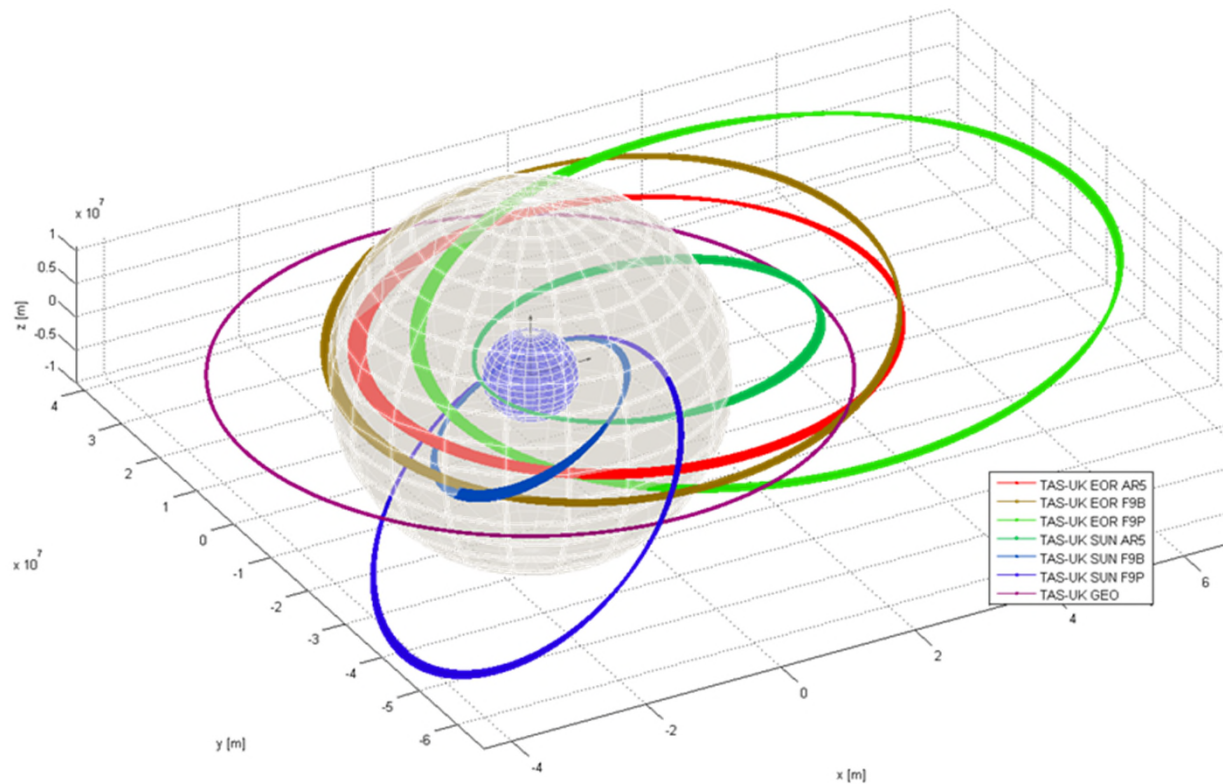
Date: 20th nov. 2019
 Ref: TAS-UK-2019-INC-OBNAV-01
 Template: 83230347-DOC-TAS-EN-006

PROPRIETARY INFORMATION
 This document is not to be reproduced, modified, adapted, published, translated in any material form in whole or in part nor disclosed to any third party without the prior written permission of Thales Alenia Space UK Ltd.
 © 2019 Thales Alenia Space UK Ltd

THALES ALENIA SPACE OPEN



AUTONOMOUS ORBIT RAISING & STATION KEEPING



Representation of GEO orbits for performance assessment of a GNSS receiver for geostationary spacecraft using electric propulsion for transfer to GEO. Credit TAS-I and TAS-UK

Date: 20th nov. 2019
Ref: TAS-UK-2019-INC-OBNAV-01
Template: 83230347-DOC-TAS-EN-006

PROPRIETARY INFORMATION
This document is not to be reproduced, modified, adapted, published, translated in any material form in whole or in part nor disclosed to any third party without the prior written permission of Thales Alenia Space UK Ltd.
© 2019 Thales Alenia Space UK Ltd

THALES ALENIA SPACE OPEN

ThalesAlenia
Space
Thales / Leonardo company

IN-ORBIT SERVICING (LEO, GEO)

- In-orbit servicing (LEO, GEO)
- In-orbit servicing (lunar)
- Lunar vicinities navigation

Date: 20th nov. 2019
Ref: TAS-UK-2019-INC-OBNAV-01
Template: 83230347-DOC-TAS-EN-006

PROPRIETARY INFORMATION
This document is not to be reproduced, modified, adapted, published, translated in any material form in whole or in part nor disclosed to any third party without the prior written permission of Thales Alenia Space UK Ltd.
© 2019 Thales Alenia Space UK Ltd

THALES ALENIA SPACE OPEN

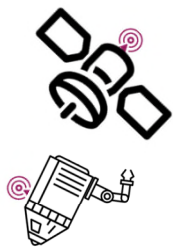
ThalesAlenia
Space
Thales / Leonardo company

IN-ORBIT SERVICING – EXEMPLE

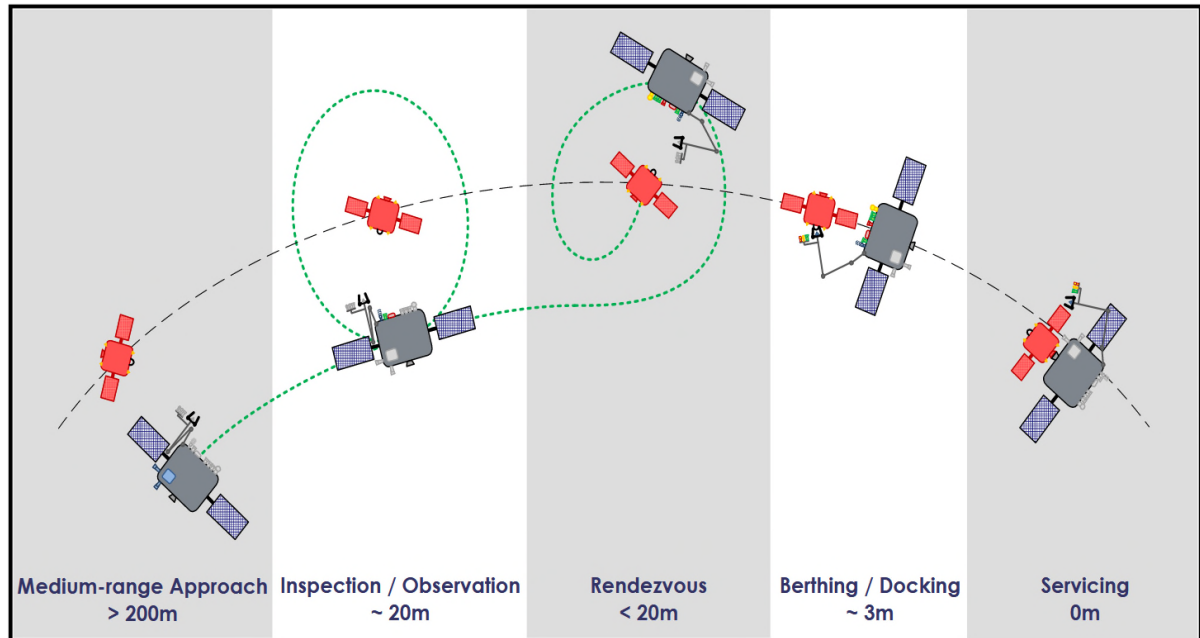
In-orbit servicing is a quite young area of interest in the space industry and aims at addressing quite a large variety of needs:

- **Repairing**
- **Refueling**
- **Relocation (orbital or positional alteration)**
- **Payload upgrade**
- **Salvage operations**

Mission phase	Distance range	Position error
Absolute navigation	1000m-200m	50m
Medium-range approach	200m-20m	2m
Fly-by and inspection	20m	0.2m
Close-range rendezvous	20m-3m	0.03m
Capture – Station keeping	3m	0.03m
Capture – Berthing/Docking	1m-0m	0.003m
Servicing	0m	0.001m



For missions where the target is still active, cooperative in-orbit servicing is achievable. The target position can then be shared and used within the POD algorithms.



The satellite switches to a relative positioning suite and approaches as close as possible using a lidar and/or a radar.

The satellite is close enough to switch on its cameras and begin the inspection process. By building a 3D model of the satellite it estimates with a high accuracy the distance with the target (0.2m) and its attitude (2.5°).

The goal of this phase is bringing the target grapple fixture within range of the operating appendix (the robotic arm).

Target and chaser are perfectly aligned and only the robotic arm now moves in order to seize the grapple fixture.

The main mission objective can now take place. This could be refuelling, repairing, ...

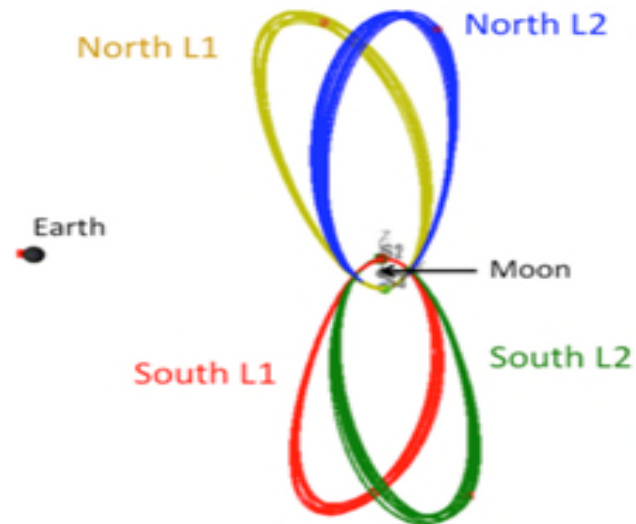
Date: 20th nov. 2019
 Ref: TAS-UK-2019-INC-OBNAV-01
 Template: 83230347-DOC-TAS-EN-006

PROPRIETARY INFORMATION
 This document is not to be reproduced, modified, adapted, published, translated in any material form in whole or in part nor disclosed to any third party without the prior written permission of Thales Alenia Space UK Ltd.
 © 2019 Thales Alenia Space UK Ltd

THALES ALENIA SPACE OPEN



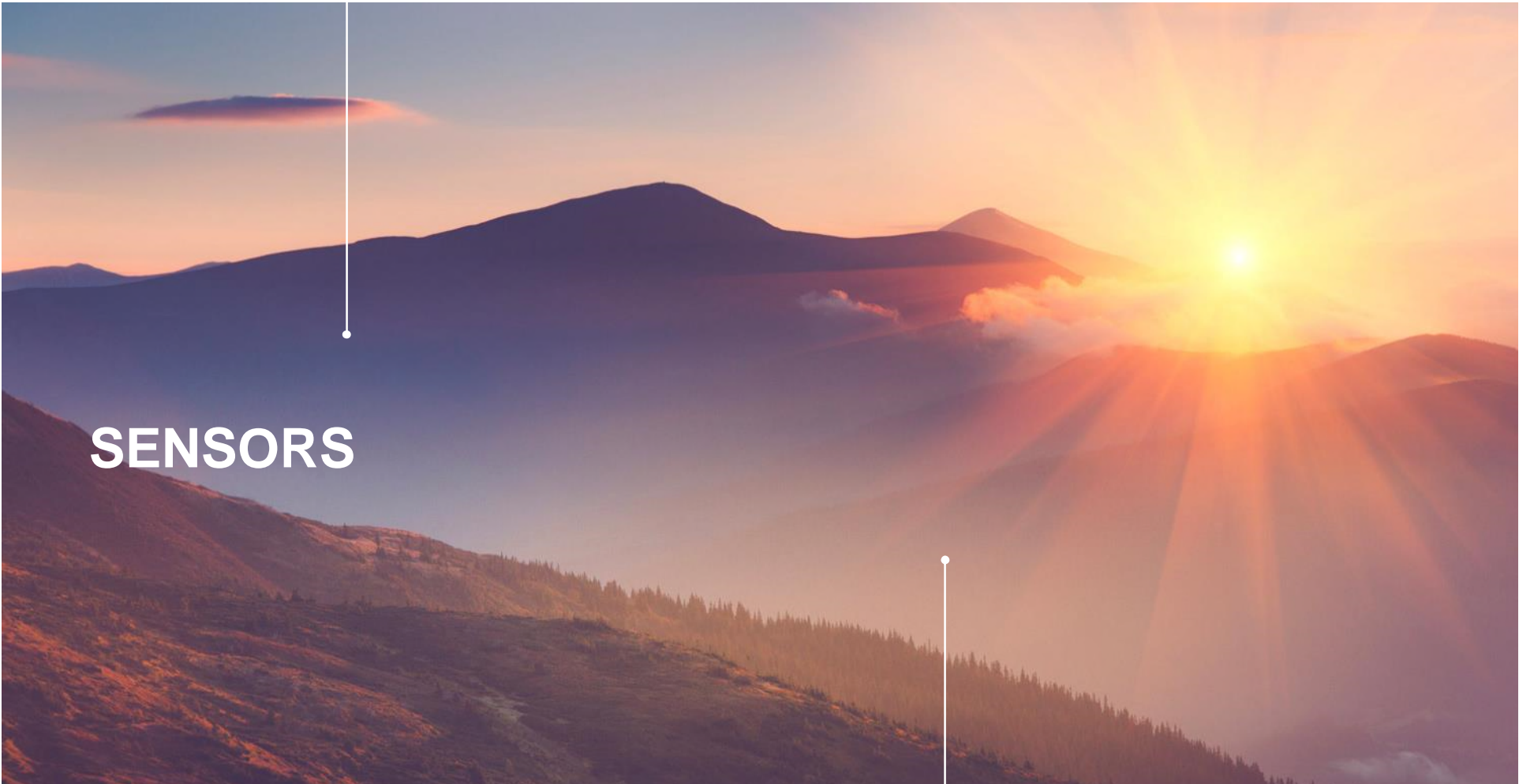
LUNAR SCENARII



Aposelenium (km)	70000
Periselenium (km)	7000
Inclination (deg)	90
Argument of periapsis (deg)	-90
RAAN (deg)	79
Mean anomaly	0

Near rectilinear orbit representation

Characteristics of the LOP-G Orbit



SENSORS

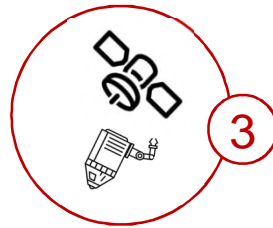
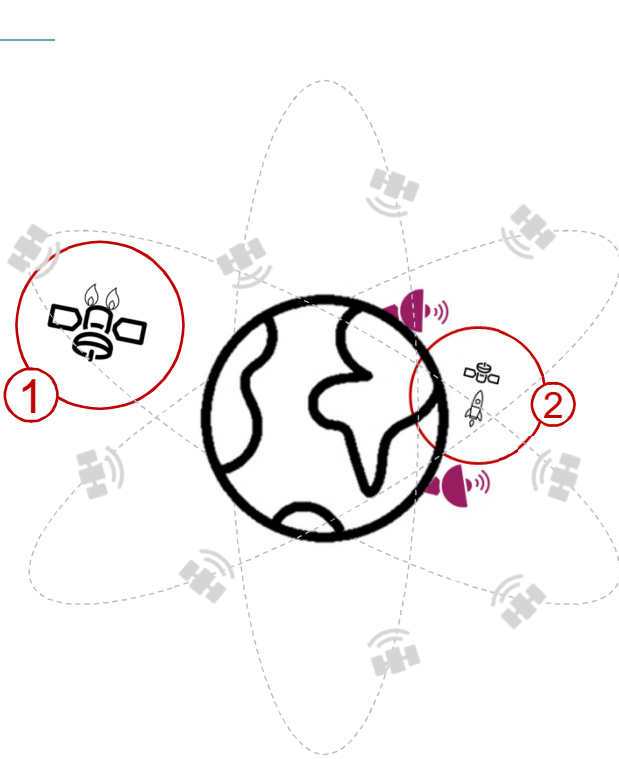
Date: 20th nov. 2019
Ref: TAS-UK-2019-INC-OBNAV-01
Template: 83230347-DOC-TAS-EN-006

PROPRIETARY INFORMATION
This document is not to be reproduced, modified, adapted, published, translated in any material form in whole or in part nor disclosed to any third party without the prior written permission of Thales Alenia Space UK Ltd.
© 2019 Thales Alenia Space UK Ltd

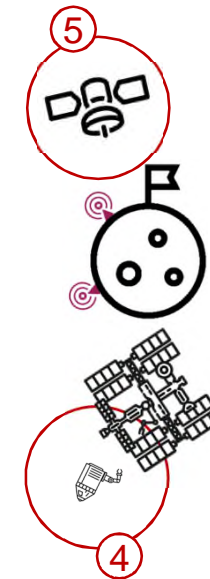
THALES ALENIA SPACE OPEN



NAVIGATION SENSORS FOR EACH SELECTED MISSIONS

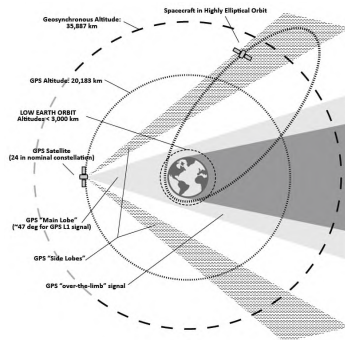


#	Mission	Potential sensors and technologies
1	Autonomous orbit raising & station keeping	GNSS INS
2	Post separation optimization	GNSS INS
3	On-orbit servicing (LEO, GEO)	GNSS INS Radar Lidar Cameras Tactile sensors
4	In-orbit servicing (lunar)	GNSS INS Radar Lidar Cameras Tactile sensors
5	Lunar vicinities navigation	GNSS INS Cameras Lunar ground support Other spacecraft

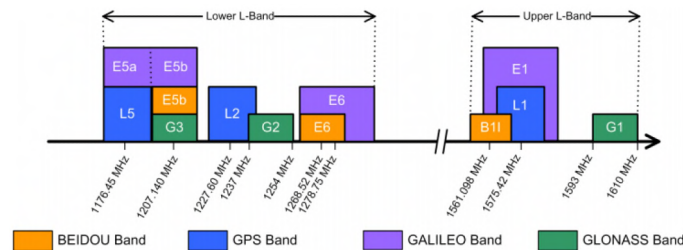


GNSS CONSTELLATIONS

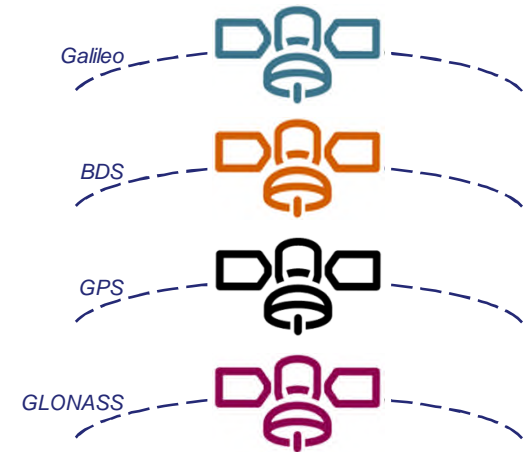
- A new GNSS environment:
 - o 4 functional GNSS constellation by 2020
 - Increase in number of satellites
 - Increase in number of frequencies
 - o Shared frequencies
 - Ease of interoperability
 - o Better characterisation of signals (e.g. side lobes)



GPS geometry for SSV characteristics⁽¹⁾



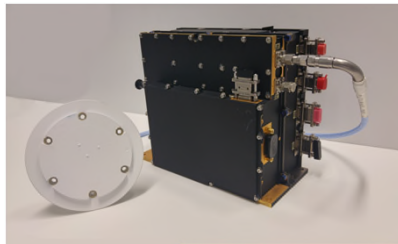
BeiDou, GPS, Galileo and Glonass frequency bands⁽²⁾



⁽¹⁾ The Interoperable Global Navigation Satellite Systems Space Service Volume.
⁽²⁾ Review of existing GNSS POD concepts. Ref. GMV-GN4SVEXT-TN-0001 - D1.

ON-BOARD GNSS RECEIVER – EXEMPLE OF TOPSTAR G2

PHOTO / HERITAGE



🚀 QUALIFICATION IN 2018, 6 FMS

🚀 EVOLUTION OF TOPSTAR G1 :

- 🚀 118 FMs since 2000.
- 🚀 > 230 years of trouble-free spaceflight heritage

FUNCTIONAL DESCRIPTION / MAIN FEATURES

- 🚀 L1 GPS+GALILEO receiver for telecom and observation satellites
- 🚀 Highly compact, low mass equipment
- 🚀 Embedded orbital navigator providing accurate Position, Velocity and Time
- 🚀 Raw data delivery

PERFORMANCE SUMMARY

🚀 Functional :

- 🚀 Cold start time TTFF : 4minutes typ, 6minutes max in LEO
- 🚀 Accuracy :
 - 🚀 Position (rms) : 4,4m (zenith pointing, LEO)
 - 🚀 Velocity (rms) : 8mm/s (zenith pointing, LEO)
 - 🚀 Time (3σ) : 100ns

🚀 Electrical

- 🚀 22V to 55V primary power bus
- 🚀 Redunded RS422 or 1553 TMTC
- 🚀 4 PPS signals (RS422 level)
- 🚀 Optional low level ON/OFF commands

🚀 Physical

- 🚀 Mass : 1,6kg
- 🚀 Dimensions : 174 x 83 x 142 mm³
- 🚀 DC Consumption :
 - 🚀 Navigation : 11,2W (12,3WC)

Date: 20th nov. 2019
Ref: TAS-UK-2019-INC-OBNAV-01
Template: 83230347-DOC-TAS-EN-006

PROPRIETARY INFORMATION
This document is not to be reproduced, modified, adapted, published, translated in any material form in whole or in part nor disclosed to any third party without the prior written permission of Thales Alenia Space UK Ltd.
© 2019 Thales Alenia Space UK Ltd

THALES ALENIA SPACE OPEN

ThalesAlenia
Space
Thales / Leonardo company

INERTIAL SENSOR: EXEMPLE OF LOW COST/MEDIUM PERFORMANCE SENSORS

HERITAGE



- 🚀 2nd Iteration of the MEMs Gyro
- 🚀 1st Iteration (SiREUS) used on Cyrosat, Sentinel 3 and MTG
- 🚀 Enhanced modification for ExoMars Rover (IMU)
- 🚀 10 Flight Sets built to date

FUNCTIONAL DESCRIPTION / MAIN FEATURES

- 🚀 Low cost, medium performance 3-axis gyro:
 - 🚀 < 1 deg/h bias stability
 - 🚀 <0.1 deg/√h ARW
- 🚀 Low mass/volume/power
 - 🚀 Simple spacecraft accommodation
- 🚀 Standardised Interface
 - 🚀 No change for gyro, accelerometer or IMU functionality

PERFORMANCE SUMMARY

🚀 Performance

	Parameter	Value
Performance	Acquisition Rate	1-200 Hz
	Range	+/- 20 deg/sec
	Resolution	< 0.36 deg/h
	Bias Stability: In Run	< 1-2 °/h
	Bias Stability: Run to Run	< 5 °/h
	Bias Instability	< 1 deg/h
	Random Walk	< 0.1 deg/√h
	Scale Factor Stability	<2000 ppm (3σ)
	Misalignment	< 60 arc-sec

🚀 Electrical

- 🚀 RS422 / UART and RS485 (Data and Power & Test Interface)

🚀 Physical

- 🚀 Mass: 750 gms

🚀 Dimensions: HxWxL

- 🚀 81 x 104 x 104mm (no feet),
- 🚀 81 x 128 x 100mm (with feet)

🚀 DC Consumption:

- 🚀 28Vdc / <5 Watts

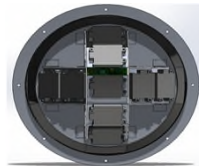
OTHER SENSORS – CREDIT I3DS H2020 PROJECT

/// RADAR/RF

/ FFRFS (FORMATION FLYING RF SENSOR)): COOPERATIVE NAVIGATION SENSOR WITH HIGH IMPACT IN MASS/COST ON THE TARGET



/ RADAR:



/// LIDAR

/ TOF (TIME OF FLIGHT)
/ LIDAR CLASS



/// Tactile Sensors

/// Start trackers (and Baffle)

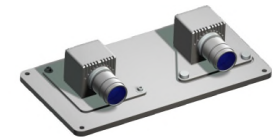


/// cameras (NUV/VIS/NIR)

/ FORWARD LOOKING INFRA RED CAMERA



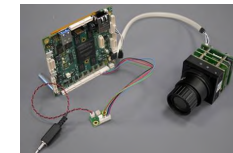
/ STEREO CAMERA



/ HIGH RESOLUTION CAMERA



/ THERMAL INFRARED CAMERA



Date: 20th nov. 2019
Ref: TAS-UK-2019-INC-OBNAV-01
Template: 83230347-DOC-TAS-EN-006

PROPRIETARY INFORMATION
This document is not to be reproduced, modified, adapted, published, translated in any material form in whole or in part nor disclosed to any third party without the prior written permission of Thales Alenia Space UK Ltd.
© 2019 Thales Alenia Space UK Ltd

THALES ALENIA SPACE OPEN

ThalesAlenia
Space
Thales / Leonardo company



PERFORMANCES ASSESSMENT

Date: 20th nov. 2019
Ref: TAS-UK-2019-INC-OBNAV-01
Template: 83230347-DOC-TAS-EN-006

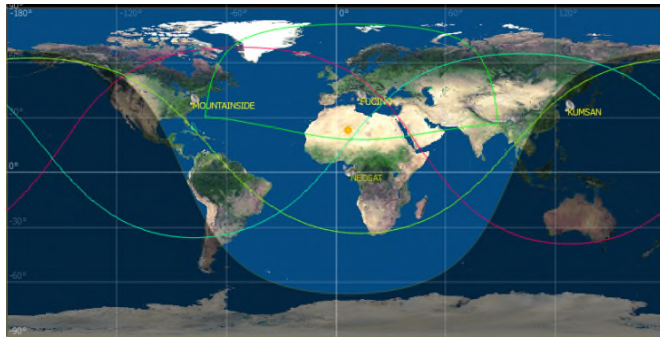
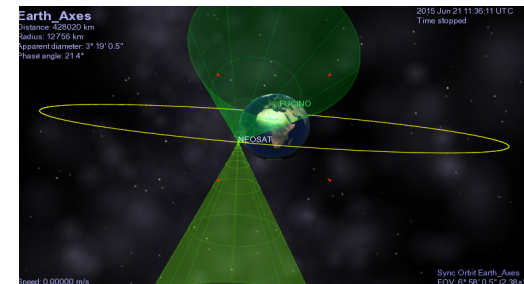
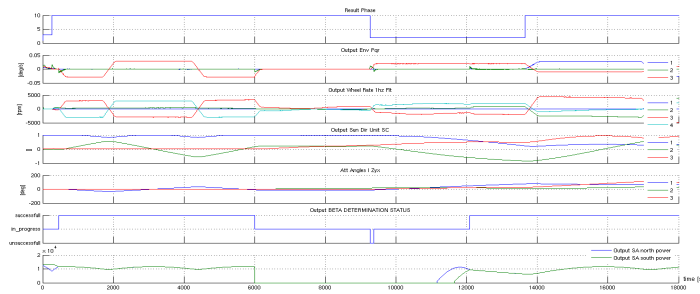
PROPRIETARY INFORMATION
This document is not to be reproduced, modified, adapted, published, translated in any material form in whole or in part nor disclosed to any third party without the prior written permission of Thales Alenia Space UK Ltd.
© 2019 Thales Alenia Space UK Ltd

THALES ALENIA SPACE OPEN

ThalesAlenia
Space
Thales / Leonardo company

TOOLS

/// Mission Analysis & Navigation performances assessment & Avionic Test Bench: TAS-UK (Harwell)



Date: 20th nov. 2019
 Ref: TAS-UK-2019-INC-OBNAV-01
 Template: 83230347-DOC-TAS-EN-006

PROPRIETARY INFORMATION
 This document is not to be reproduced, modified, adapted, published, translated in any material form in whole or in part nor disclosed to any third party without the prior written permission of Thales Alenia Space UK Ltd.
 © 2019 Thales Alenia Space UK Ltd

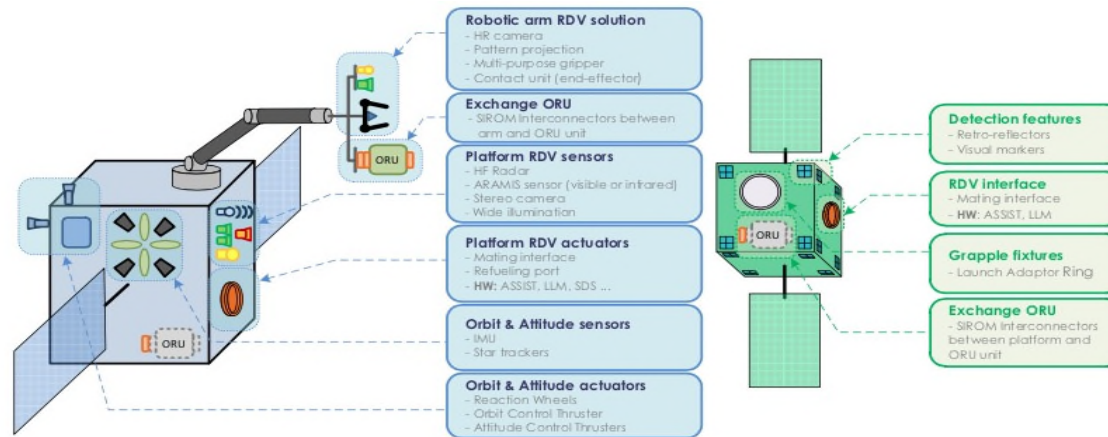
THALES ALENIA SPACE OPEN



TOOLS

/// ROBOTIC MISSIONS & ON-ORBIT SERVICING test bed – (TASF, Cannes)

- 🚀 Generic building blocks to be instantiated per mission (rendez-vous, servicing, robotic exploration & science)
 - 🚀 Specifics in terms of autonomy & FDIR
 - 🚀 High frequency control loops & decision making requires high autonomy (e.g.: CAM, path planning)
 - 🚀 Advanced FDIR with maximisation of Fail-Op recoveries



Date: 20th nov. 2019
 Ref: TAS-UK-2019-INC-OBNAV-01
 Template: 83230347-DOC-TAS-EN-006

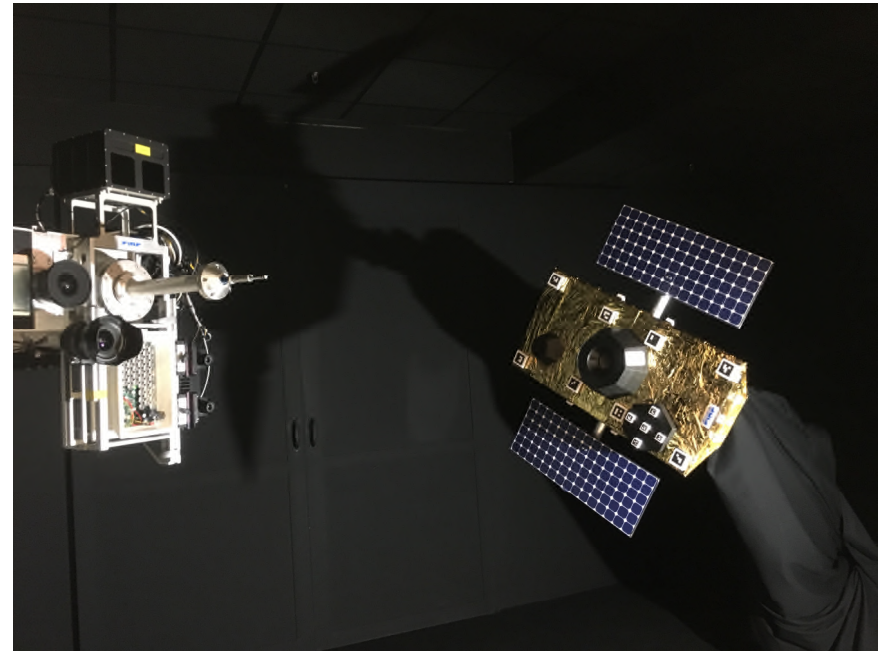
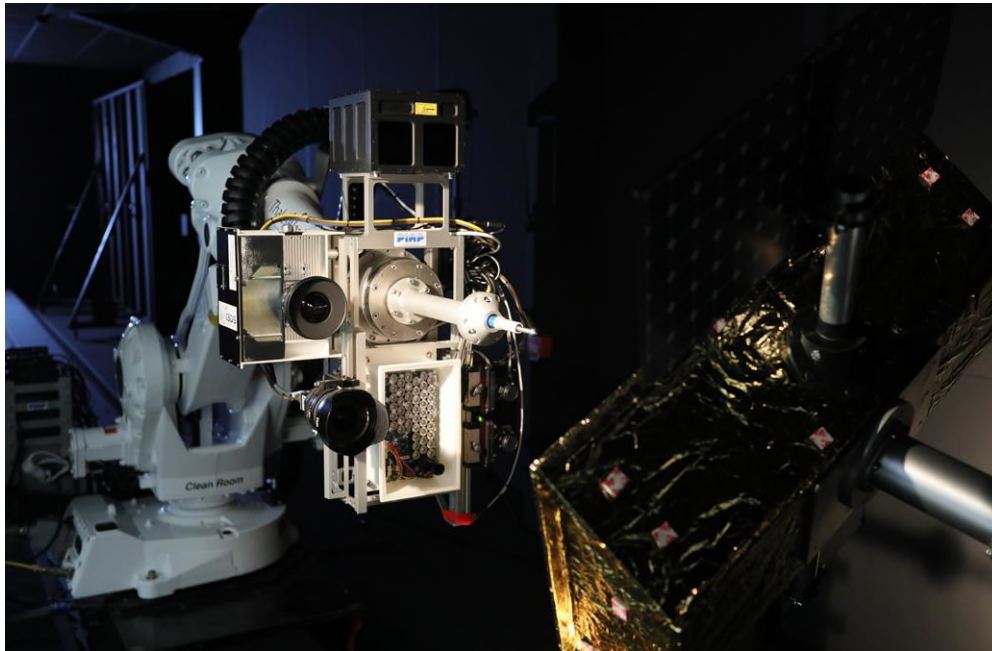
PROPRIETARY INFORMATION
 This document is not to be reproduced, modified, adapted, published, translated in any material form in whole or in part nor disclosed to any third party without the prior written permission of Thales Alenia Space UK Ltd.
 © 2019 Thales Alenia Space UK Ltd

THALES ALENIA SPACE OPEN



TOOLS

/// ROBOTIC MISSIONS & ON-ORBIT SERVICING test bed – (TASF, Cannes)



Date: 20th nov. 2019
Ref: TAS-UK-2019-INC-OBNAV-01
Template: 83230347-DOC-TAS-EN-006

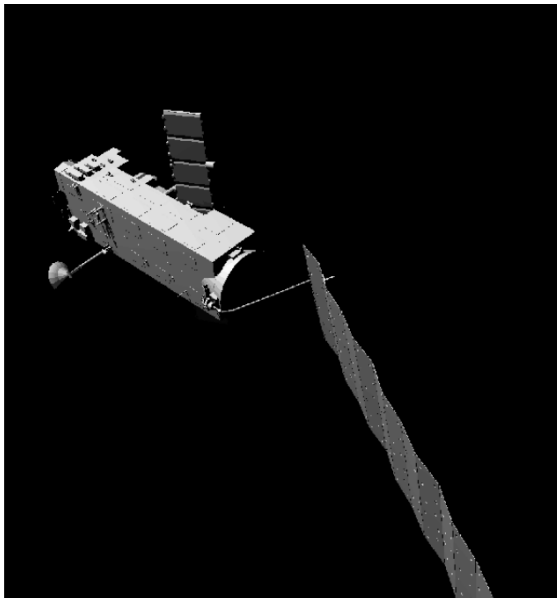
PROPRIETARY INFORMATION
This document is not to be reproduced, modified, adapted, published, translated in any material form in whole or in part nor disclosed to any third party without the prior written permission of Thales Alenia Space UK Ltd.
© 2019 Thales Alenia Space UK Ltd

THALES ALENIA SPACE OPEN

ThalesAlenia
Space
a Thales / Leonardo company

TOOLS

/// Spicam tool (Spacecraft and Planetary Image by CAmera Modelling), TASF, Cannes)



Example of images generated by SpiCam tool:
(Left: Envisat – Right: Ganymede and Jupiter)

Date: 20th nov. 2019
Ref: TAS-UK-2019-INC-OBNAV-01
Template: 83230347-DOC-TAS-EN-006

PROPRIETARY INFORMATION
This document is not to be reproduced, modified, adapted, published, translated in any material form in whole or in part nor disclosed to any third party without the prior written permission of Thales Alenia Space UK Ltd.
© 2019 Thales Alenia Space UK Ltd

THALES ALENIA SPACE OPEN





CONCLUSION

Date: 20th nov. 2019
Ref: TAS-UK-2019-INC-OBNAV-01
Template: 83230347-DOC-TAS-EN-006

PROPRIETARY INFORMATION
This document is not to be reproduced, modified, adapted, published, translated in any material form in whole or in part nor disclosed to any third party without the prior written permission of Thales Alenia Space UK Ltd.
© 2019 Thales Alenia Space UK Ltd

THALES ALENIA SPACE OPEN

ThalesAlenia
Space
Thales / Leonardo company

CONCLUSION

/// No sensor could deliver an exhaustive navigation solution, but the right suite of sensors and software should deliver the right on-board navigation

/// The “Graal” of a full autonomous satellite is more and more accessible: some phases of life of satellite, like On-Station keeping for GEO, could nearly be fully autonomous today

/// Autonomy is increasing in most of the space systems, and will :

- / OFFER EASIER AND MORE COST EFFECTIVE OPERATIONS
- / ENABLE NEW MISSIONS, IMPOSSIBLE OTHERWISE
- / INCREASE AVAILABILITY & ROBUSTNESS OF SPACE SYSTEMS

/// Research go on for assessing more in details the performances of on-board navigation and impact on In-Orbit Servicing. And tools, test means and scenario data are today available.

/// Promising application to come, with exciting missions like LOP-G, HERACLES, MSR (Mars Sample Return), In-Orbit Servicing, HERA

/// Thales Alenia Space is keen to go on delivering cutting-edge solution & technologies for on-board navigation, guidance and control

Date: 20th nov. 2019
Ref: TAS-UK-2019-INC-OBNAV-01
Template: 83230347-DOC-TAS-EN-006

PROPRIETARY INFORMATION

This document is not to be reproduced, modified, adapted, published, translated in any material form in whole or in part nor disclosed to any third party without the prior written permission of Thales Alenia Space UK Ltd.
© 2019 Thales Alenia Space UK Ltd

THALES ALENIA SPACE OPEN

ThalesAlenia
Space
Thales / Leonardo company