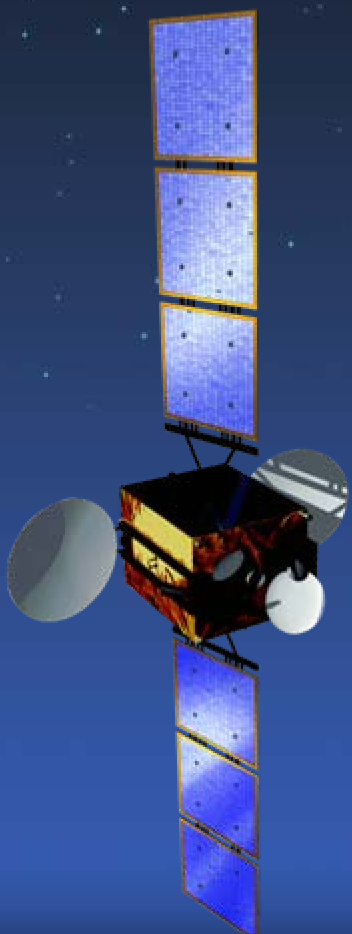
SURREY SATELLITE TECHNOLOGY LTD *Changing the economics of space*



RAPID DEVELOPMENT OF NAVIGATION PAYLOADS FOR GALILEO FULL OPERATIONAL CAPABILITY

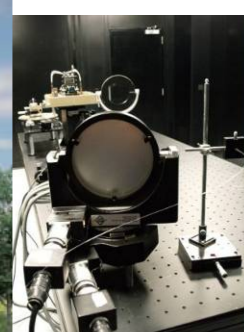
Alex da Silva Curiel

Dubai, January 2011

SSTL - the company

UK-based satellite manufacturing company owned by EADS Astrium NV (99%) and the University of Surrey (1%)

- Formed in 1985, the Company now employs >320 staff and occupies dedicated facilities in Surrey, Kent & Colorado



A history of success

34 Satellites completed – c.200 satellite years on-orbit experience
10 Further satellites (35-43) - currently being prepared for launch
18 payloads in progress (4 optical, 14 navigation)

HERITAGE: Flight proven - *low risk*

RESULTS: All projects *fixed price*, delivered *on-time* and *on-budget*

SUCCESS: Very high *mission success* – 100% mission success in last 10 years – proven equipment and full redundancy

CUSTOMERS: Variety of customers including many "blue chip" operators as well as 15 successful training programmes






UK SPACE AGENCY · esa · deimos IMAGING · MDA · Los Alamos NATIONAL LABORATORY · EADS astrium · ThalesAlenia Space · OHB SYSTEM An OHB Technology Company

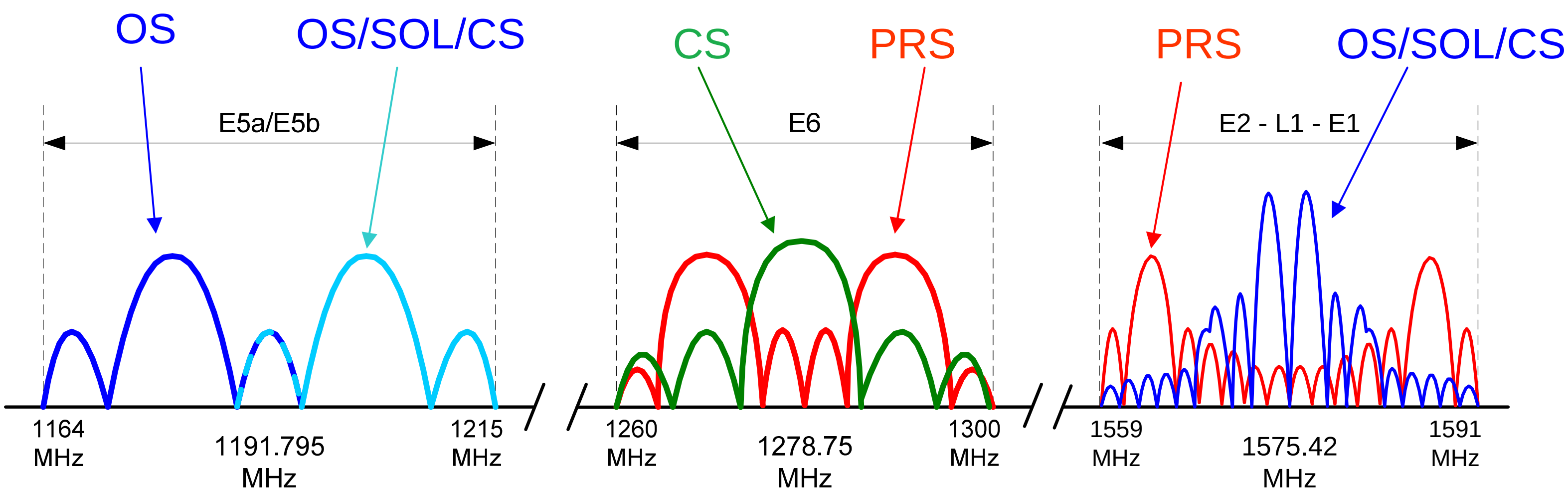
What is Galileo?

***Galileo** is a joint initiative of the European Commission (EC) and the European Space Agency (ESA). Galileo will be Europe’s own global navigation satellite system, providing a highly accurate, guaranteed global positioning service under civilian control. It will be inter-operable with GPS and GLONASS, the two other global satellite navigation systems*

Galileo Services

- Galileo offers 5 services:
  - **Open signal**, *dual frequency, mass market use*
  - **Commercial signal**, *better accuracy, service guarantee – authenticated data*
  - **Safety-of-Life signal**, *high integrity service certified for use in safety related applications*
  - **Search & Rescue**, *allows emergency services to locate users "in distress"*
  - **Public Regulated signal**, *for use by government approved users*

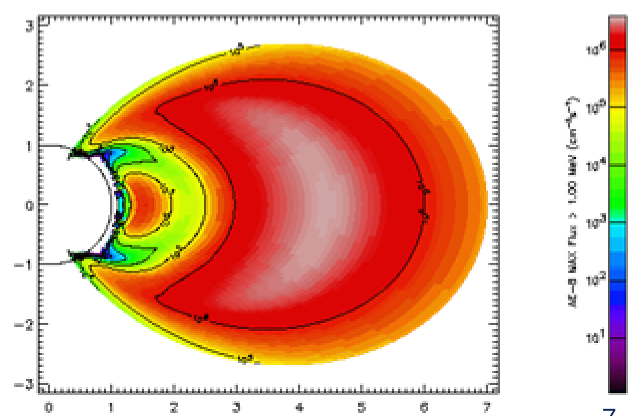
Galileo Signals



• Open Service (OS)	L1E1E2, E5a, E5b
• Commercial Service (CS)	E6
• Safety-of-Life Service (SOL)	L1E1E2, E5b
• Public Regulated Service (PRS)	L1E1E2, E6
• SAR Downlink	1544-1544.2 MHz

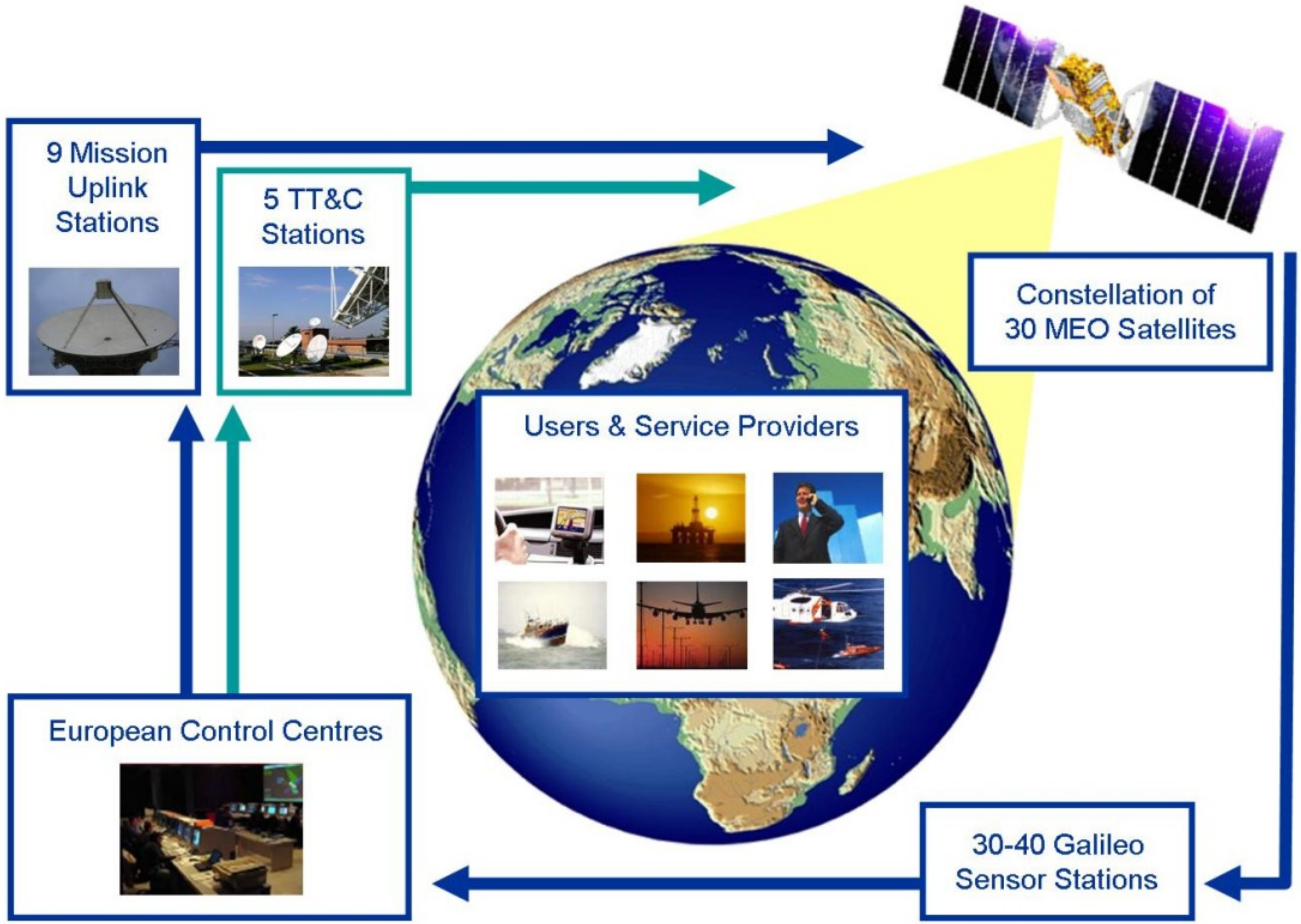
SSTL's First Role – GIOVE-A Satellite

- GIOVE-A was the first Galileo Satellite
- Test bed for claiming ITU frequencies, flight testing Galileo equipment, generating representative signals and characterising radiation environment – required 2 year life (now operating for >4 years)
- Delivered in 28months for €28M; launched 28 December 2005, Navigation signals generated 12 January 2006
- 2008 – ESA declares "Full Mission Success"



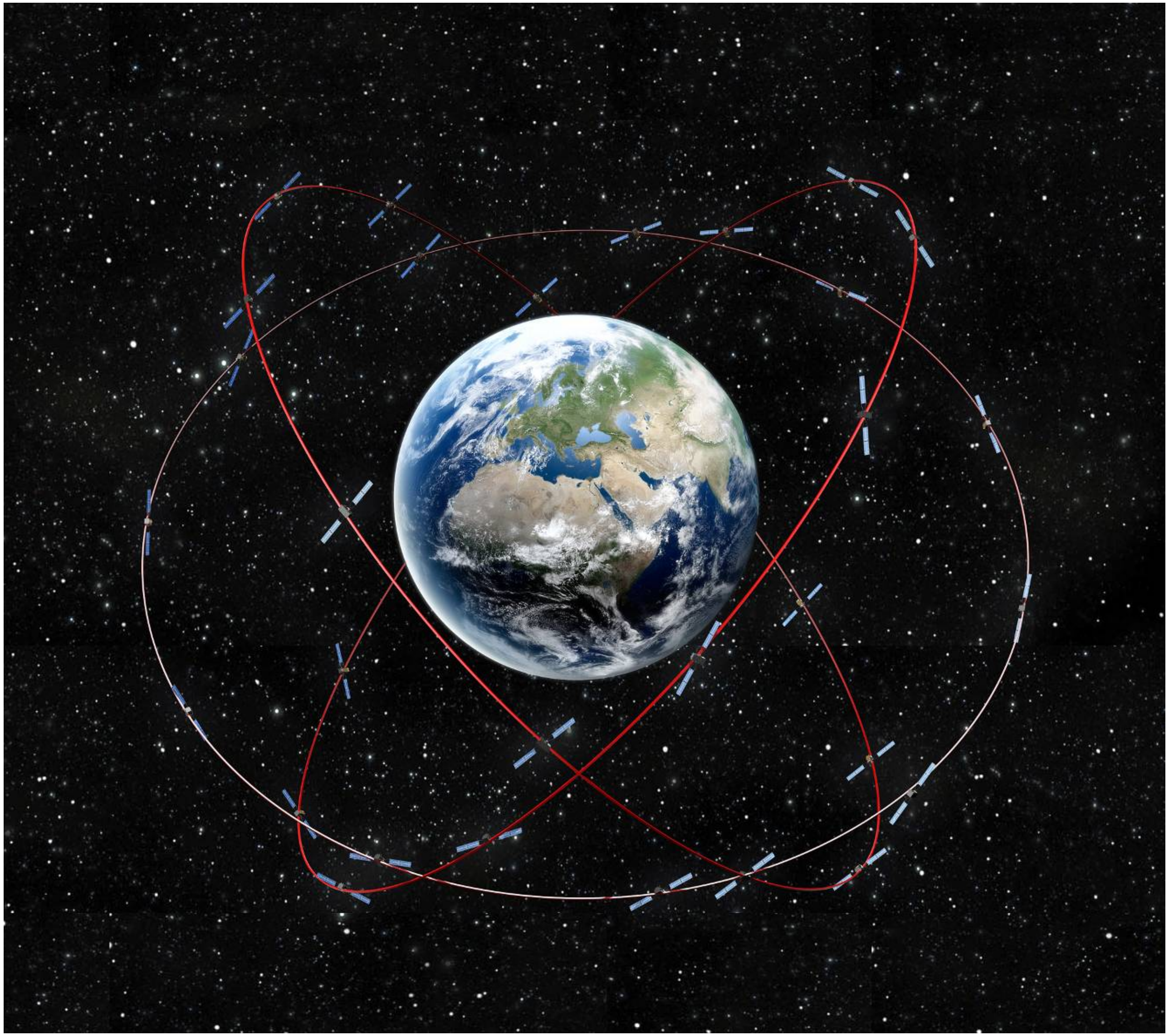
The System

- Satellites, Launchers, Ground Systems



The Constellation

- FOC is 30 satellites 27 plus 3 on-orbit spares



The Satellites

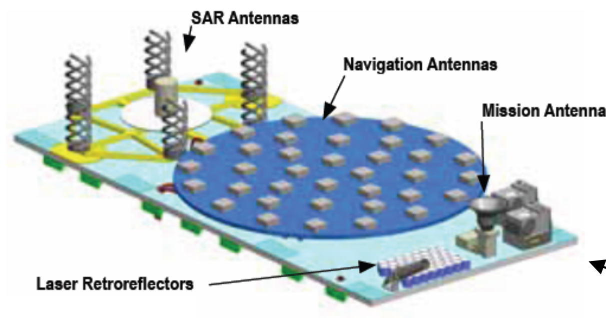
- Mass 730kg, 2.5 x 1.2 x 1.1m, Span 14.9m, 12 Year Life

Deltas GIOVE-A -> FOC

- Lifetime: 12 years vs. 2 years
- Launch: 2x (Soyuz) or 4x (Ariane)
- Services: All
- Performance: PHM for better clock stability
- Interfaces: Standard GCS/GMS interfaces
- Security: Added
- Production: Production line required

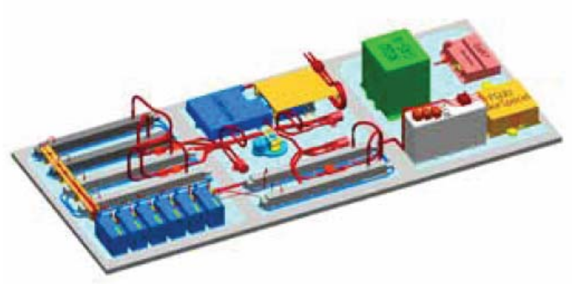
Navigation Payload

- Delivered as set of 3 panels per satellite:
  – Clock module, Antenna module, Core module

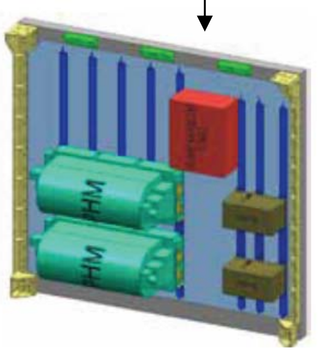


Antenna module

Galileo Payload



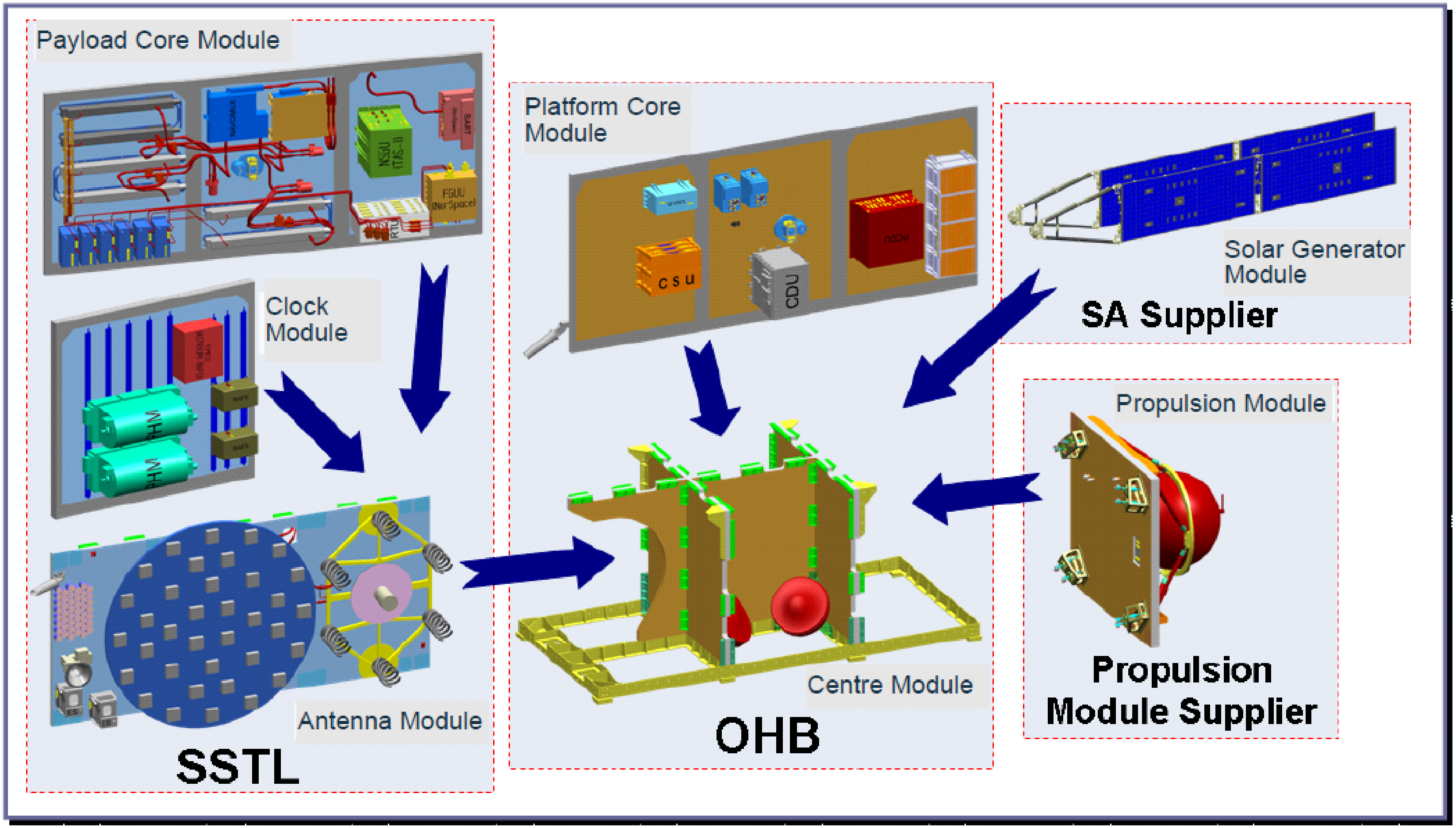
Payload Core module



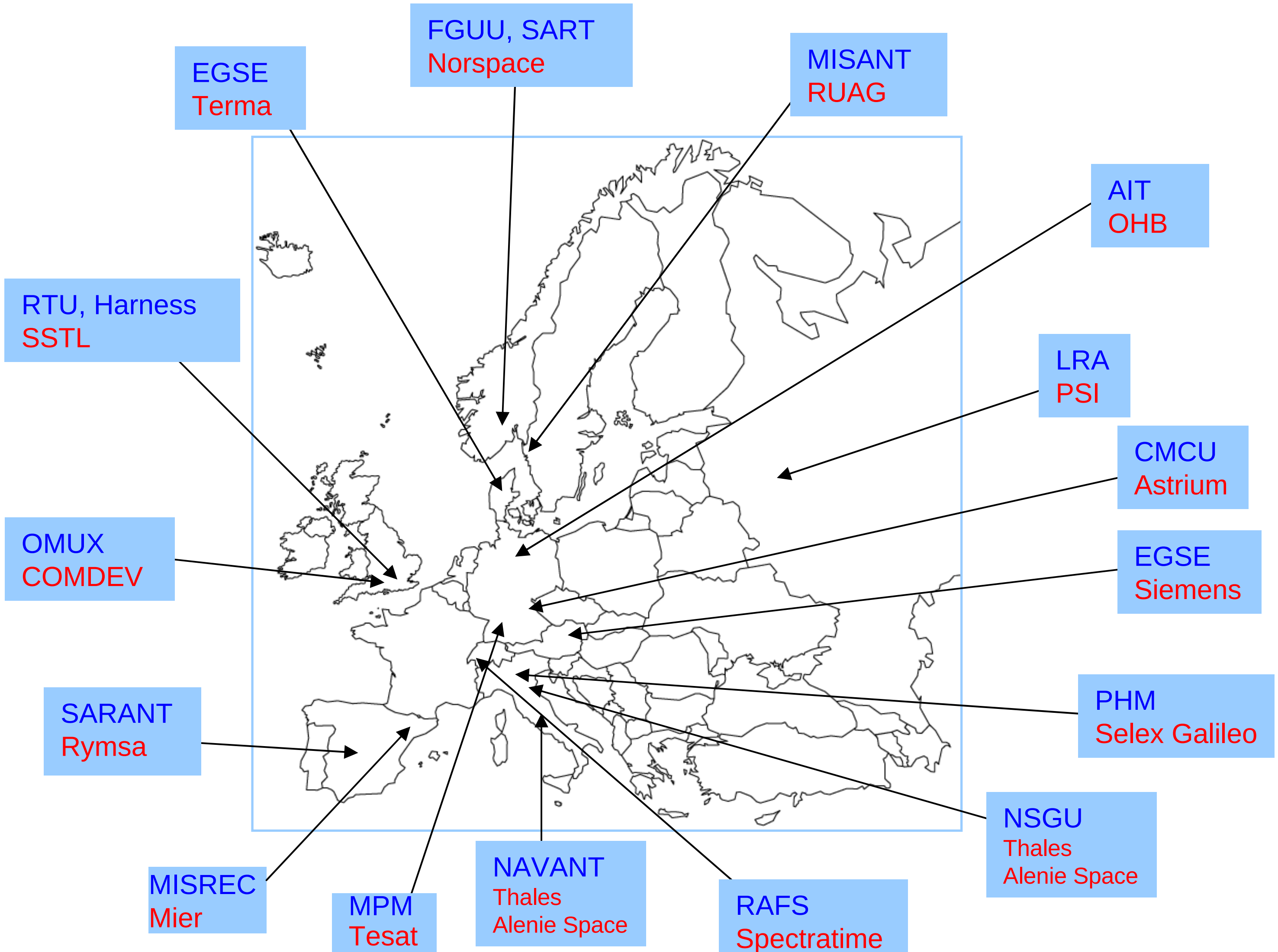
Clock module

Modular Satellite Design

- Allows bus and payload to be developed in parallel



Payload Equipment Suppliers



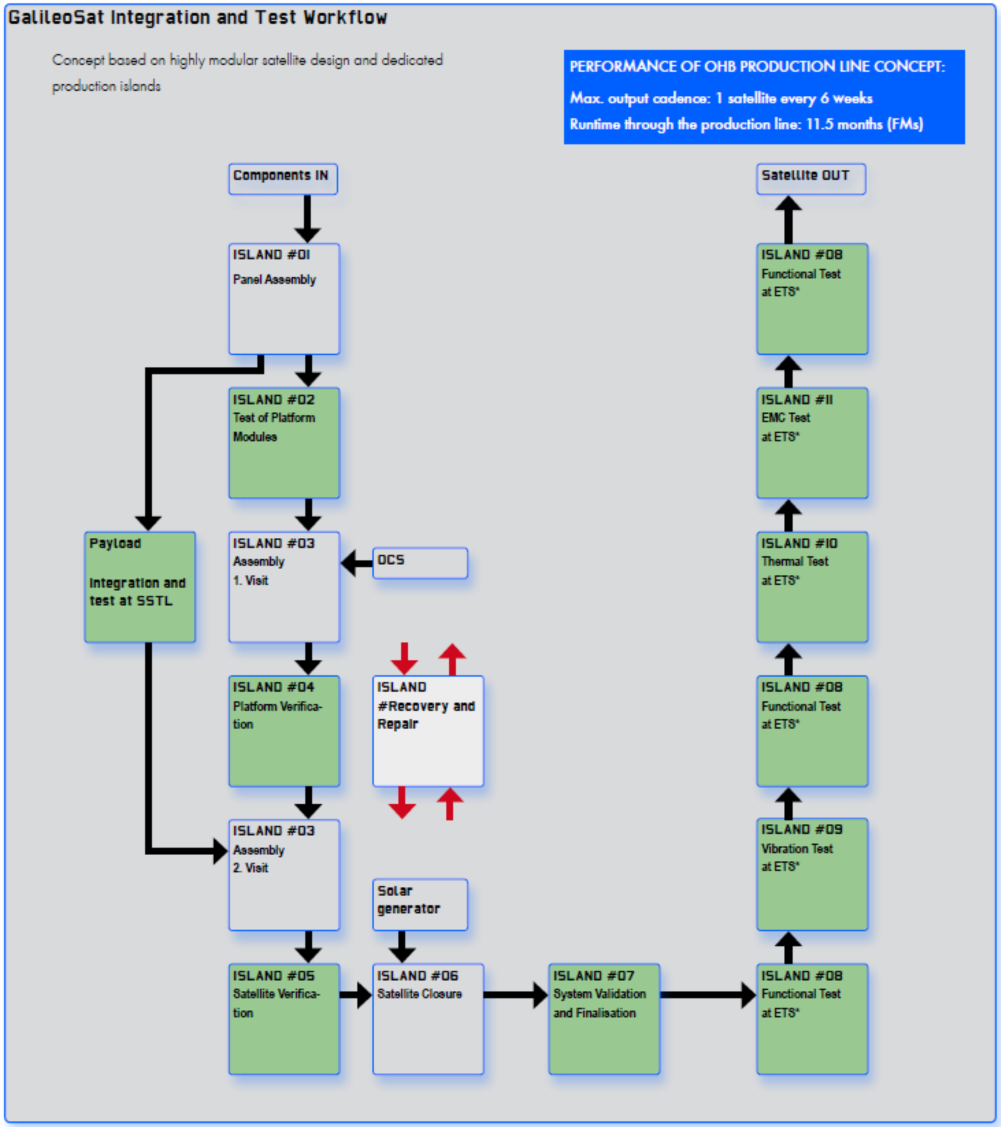
Facilities for Payload AIT

New facilities being built next to SSTL HQ building

- SSTL investment
- Building work started on 1st June 2010
- Completed spring 2011
- Project will start using existing facilities co-located at Uni Surrey

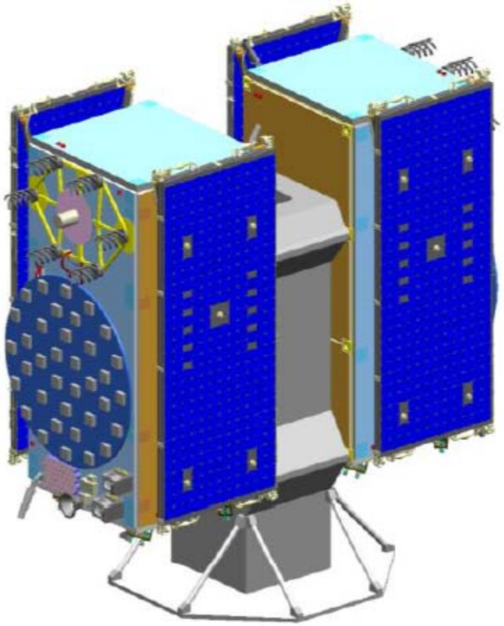
Satellite Model Philosophy & Production (AIT)

- Development Models (2):
  - Structural model & engineering model (SM, EM)
- Flight Models (14):
  - Protoflight model, flight models (PFM, FM)
- Payload integration and test in Guildford
- “Island” approach to satellite integration and test in Bremen

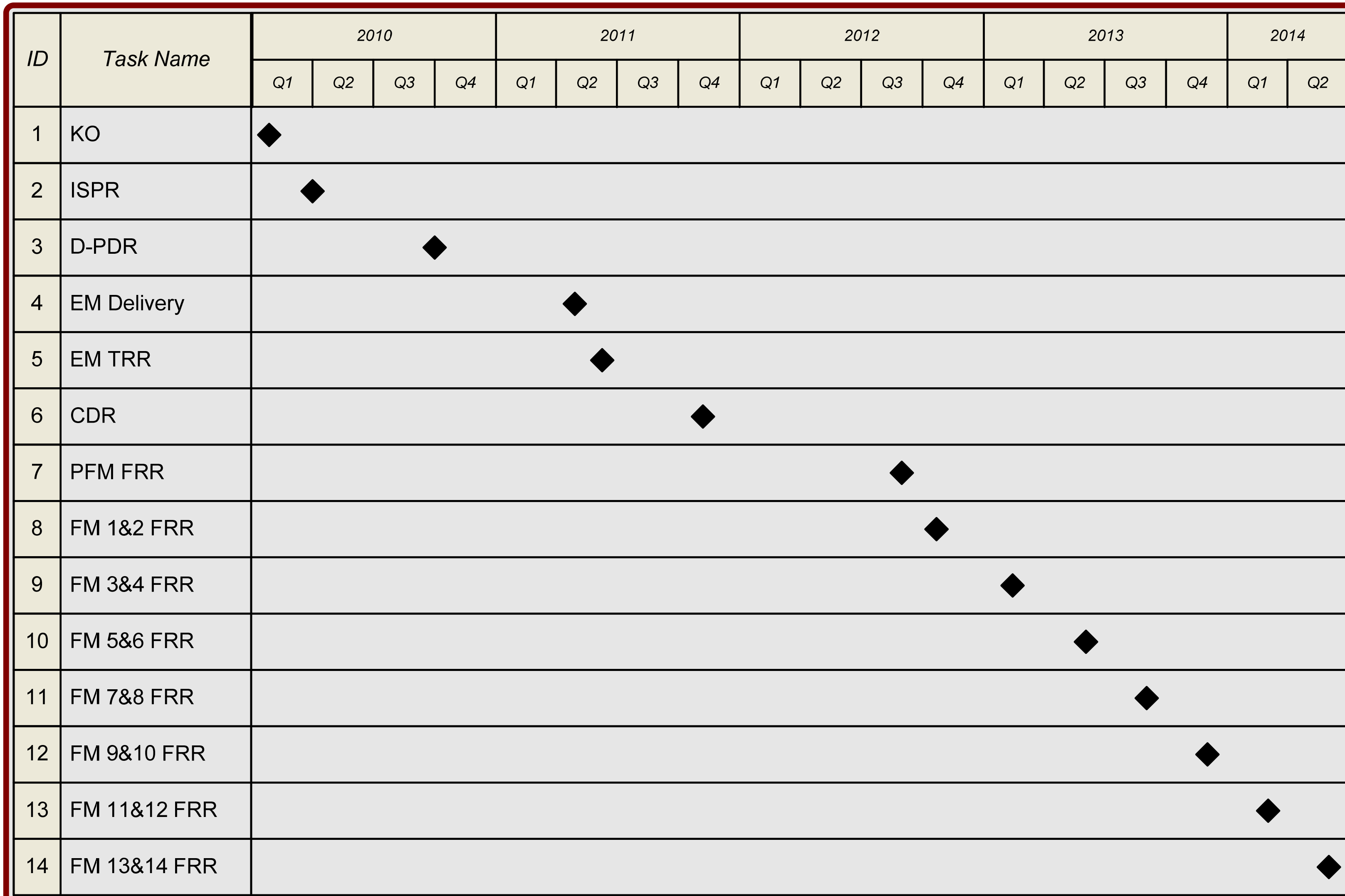


Launch

- Initial launch contract from ESA to Arianespace using Soyuz-Fregat from French Guyana
- 5 Soyuz, 2 satellites per launch
- Possibility of 4 satellites per Ariane-5 for later launches

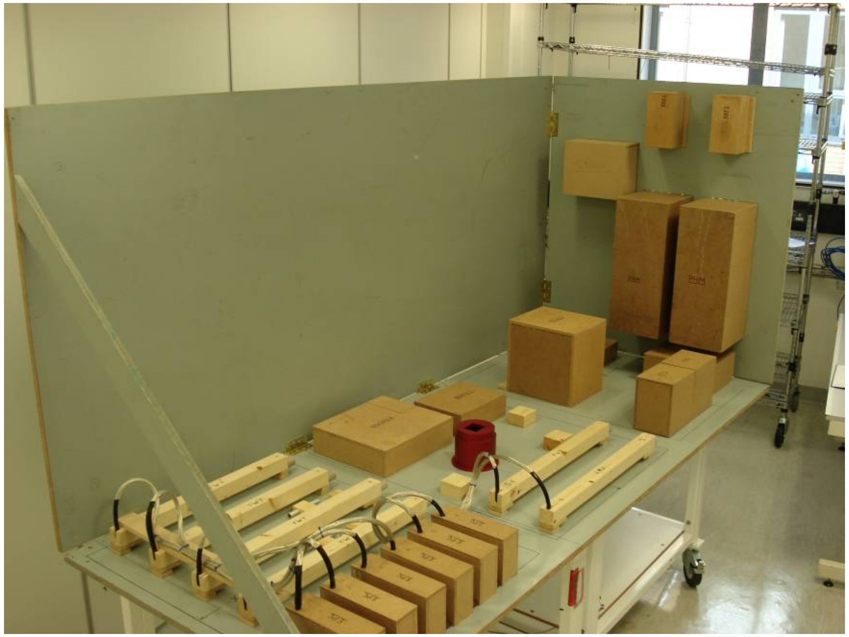


Programmatics



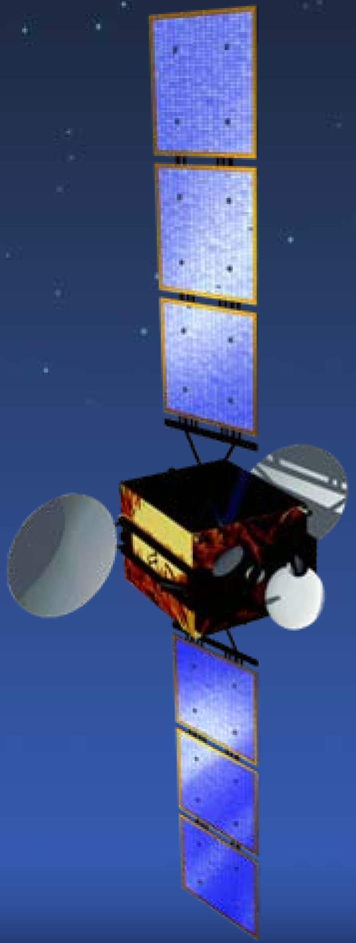
Galileo FOC Satellites – Current Status

- SSTL project team in place
- Major subcontractors kicked-off
- D-PDR – Completed, Autumn 2010
- Next major milestone – EM Delivery



MDF Harness Jig in AIT

Regional Navigation System Options



SBAS

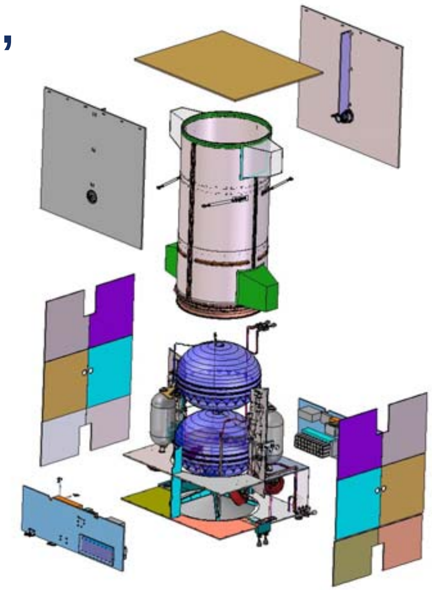
- Current Space Based Augmentation Systems
  - Broadcast integrity information and differential corrections to supplement GPS/GLONASS service for safety-of-life users
  - Single-frequency signals at GPS L1 (1575.42 MHz)
  - WAAS in US, EGNOS in Europe, MSAS in Japan
  - SBAS payloads currently leased on Inmarsat GEO satellites
- Inmarsat-4 satellites have upgraded navigation payload
  - Dual-frequency signals at GPS L1 and L5 (1176.45 MHz)
  - L1 signals will have wider bandwidth
- Inmarsat satellites positioned over oceans
  - Poor coverage over large land-masses
  - Only one WAAS satellite visible to vast majority of users in continental US
  - Represents single point of failure

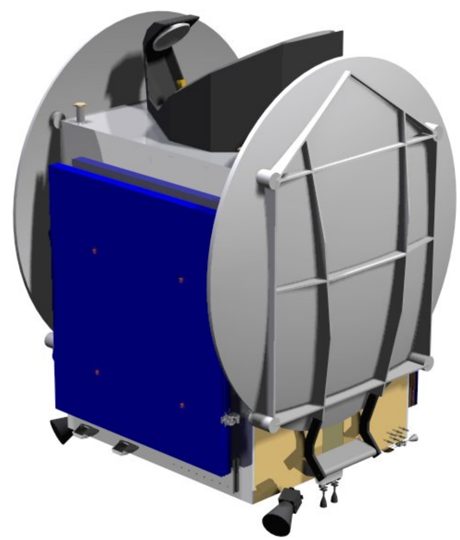
SBAS Expansion

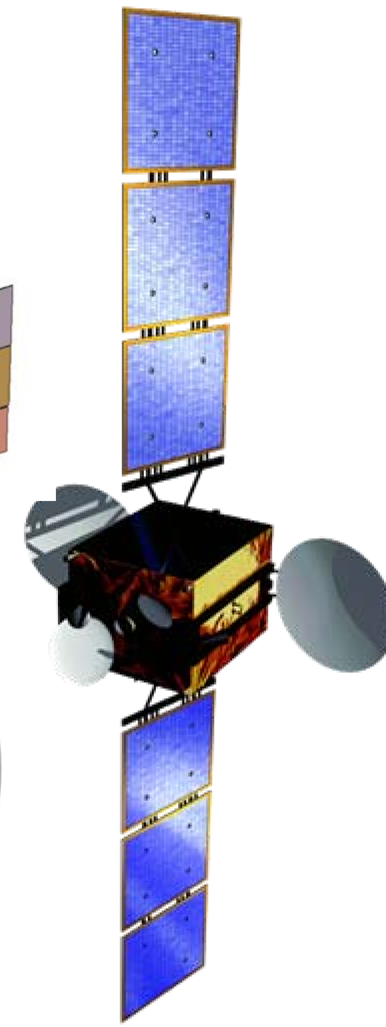
- SBAS service providers are eager to expand availability of GEO transponders
  - Piggyback opportunities on commercial GEO sats are expensive, rare, & non-optimal orbital positions
- Service providers could consider dedicated SBAS satellites
  - Low cost satellite could be good solution if cost competitive with piggyback options
- Payload can be either bent-pipe or regenerative
- Bent-Pipe
  - Similar to Inmarsat payload design, directly compatible with WAAS, etc.
  - But bent-pipe configuration uses two independent clock sources (one in ground station, one on satellite), and difficult to maintain code/carrier coherency of broadcast signals
- Regenerative payload
  - Signals derived from one on-board clock, so coherent
  - Modulators should be programmable, can vary signals

GMP - Geostationary modular platform

- **“Beyond LEO” - designed for MEO, GEO, HEO, Interplanetary Orbits**
- **Three variants:**
  - GMP-D, Direct Injection
  - GMP-T, GTO Injection
  - GMP-L, Electric Propulsion
- **Key parameters:**
  - 12+ year design life
  - Station keeping through hydrazine or bi-prop propulsion system
  - Modular & flexible design
  - Payload accommodation (GMP-T)
    - 200kg, 2.5kW (Typical comms)
    - 260kg, 1.0kW (Other apps)
- **Flight heritage:**
  - ESA GIOVE-A (2005-)
  - Development through ESA ARTES-4

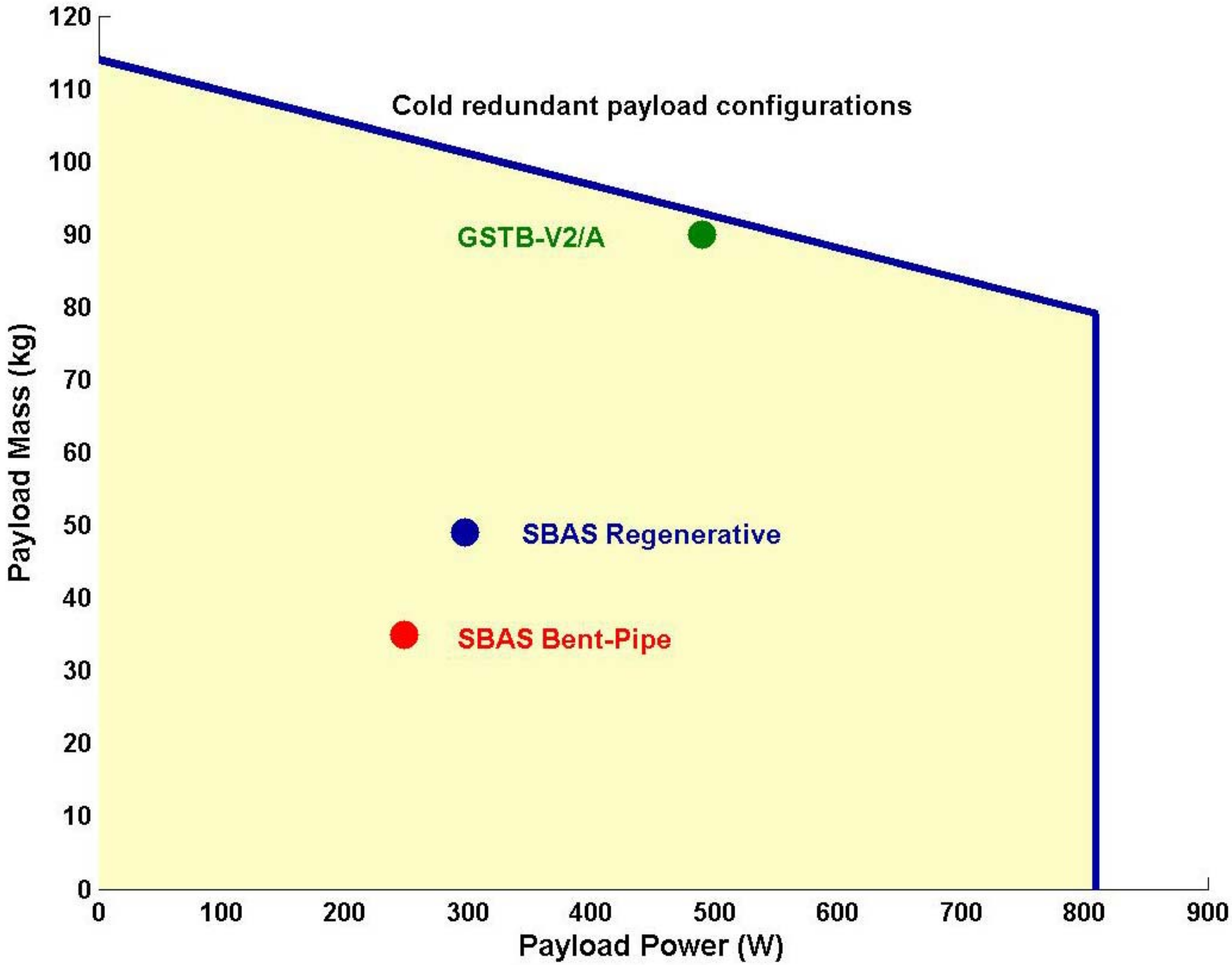






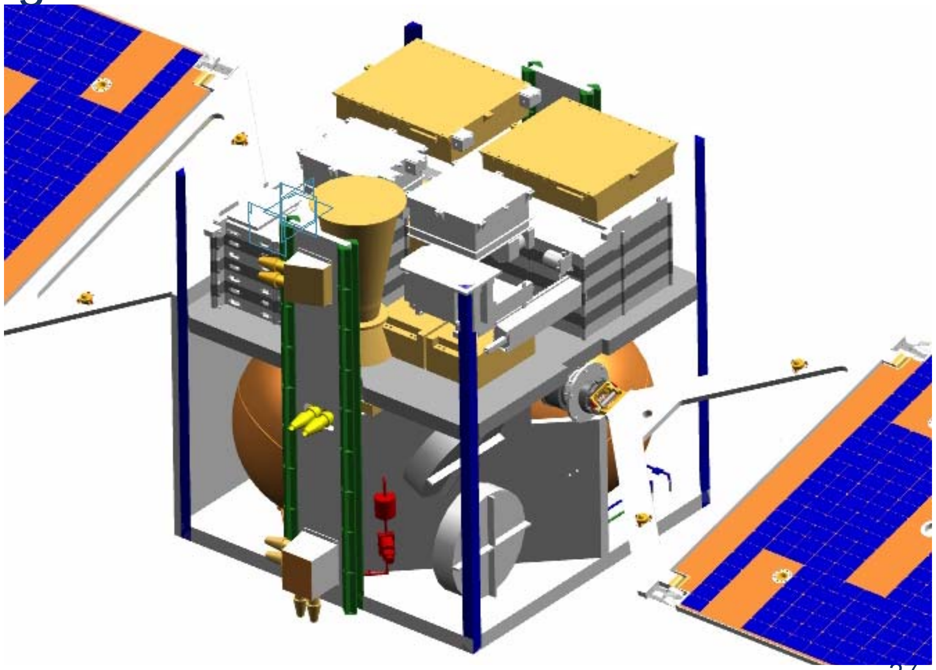
GMP-D Payload Capability

- Navigation payloads easily accommodated on GMP-D



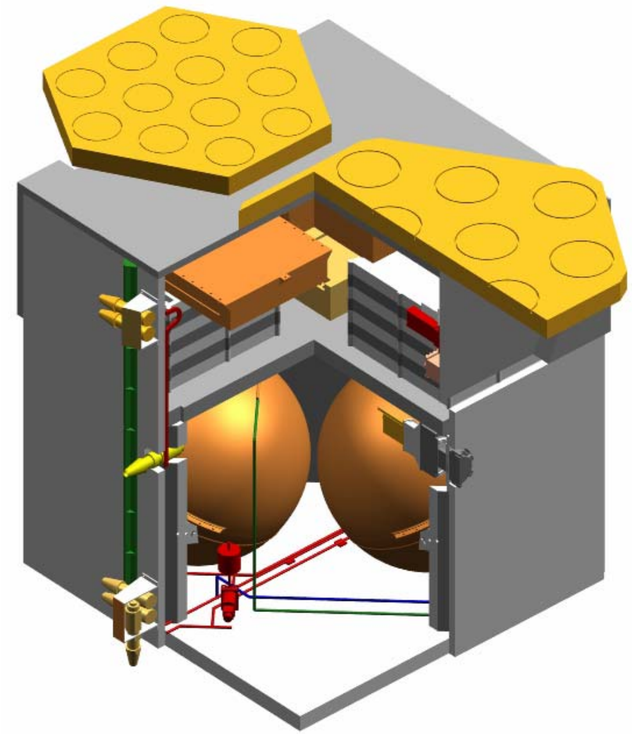
SBAS Bent-Pipe Payload

- Based on GMP-D platform (GIOVE-A heritage)
- Carries Inmarsat-4 –type navigation payload
  - Broadcasts dual-frequency signals at GPS L1 and L5
- Simple payload
  - Receive C-band uplink signals, downconvert to IF of 450 - 500 MHz, filter and amplify IF, upconvert to L-band
  - Requires no knowledge of signal modulation or data streams



SBAS Regenerative Payload

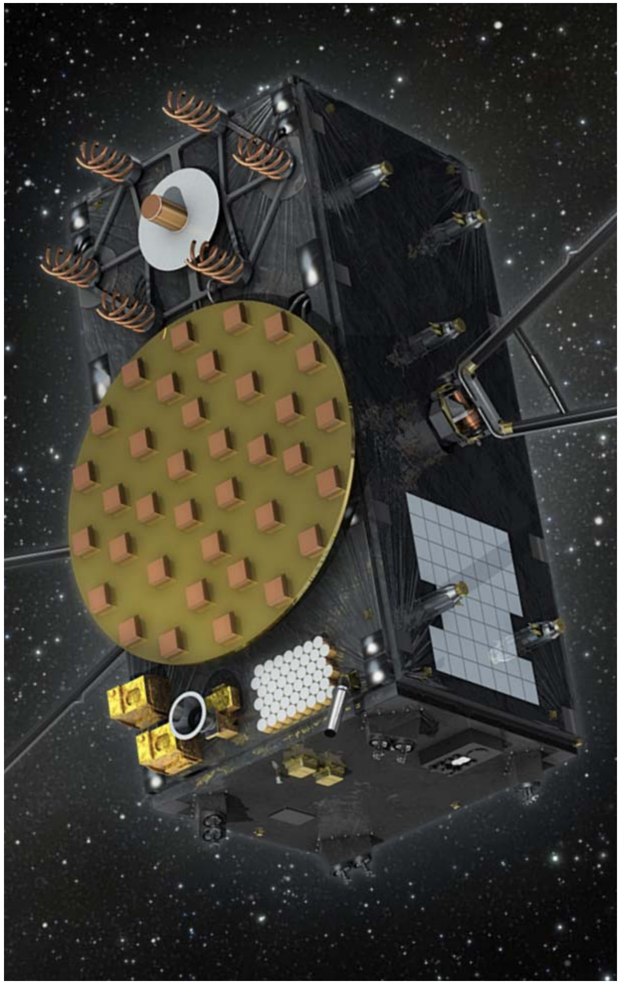
- Payload generates SBAS signals onboard the satellite
  - Retrieves integrity and navigation data from uplinked signals
  - Generates SBAS data messages and spreading codes
  - Broadcasts SBAS signals at GPS L1 and L5
- Signals compatible with Inmarsat-4 service
- Directly achieve code/carrier coherency
- Requires 10.23 MHz Rubidium atomic frequency standard onboard the satellite
- Some programmability in FPGA-based signal generator



Conclusions

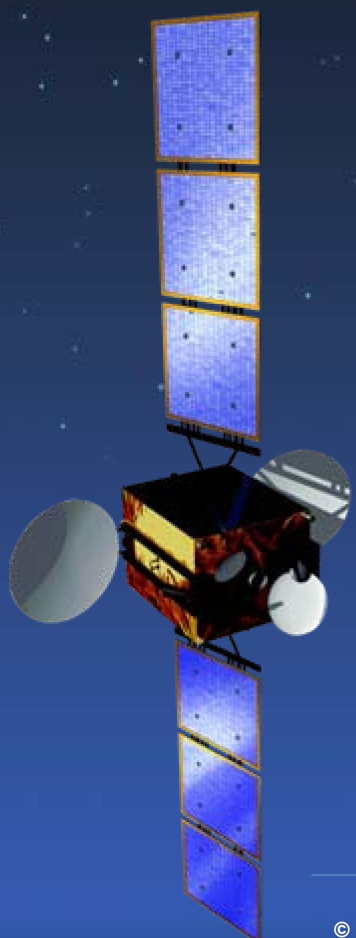
- **Galileo FOC Space Segment:**
  - 18 satellites now under contract
    - 4 IOV satellites
    - 14 FOC satellites
  - OHB/SSTL FOC satellites build on prior company experience:
    - GIOVE for the payload
  - FOC satellites
    - In design
    - Major subcontractors chosen
    - "design for manufacture"
    - Satellite production line starting in 2012

- **SBAS can be cheaply implemented as dedicated satellites**
  - Offers low cost rapid way to achieve redundant signals
  - Either Bent-pipe option (as currently implemented)
  - Or regenerative payload



Changing the economics of space

Thank you



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