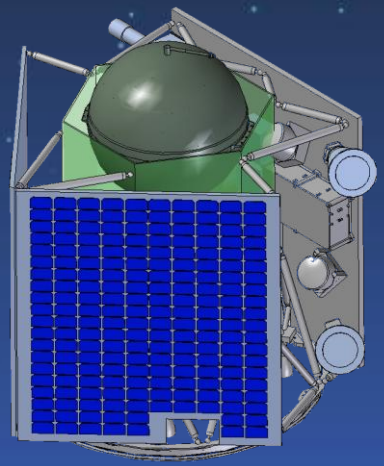
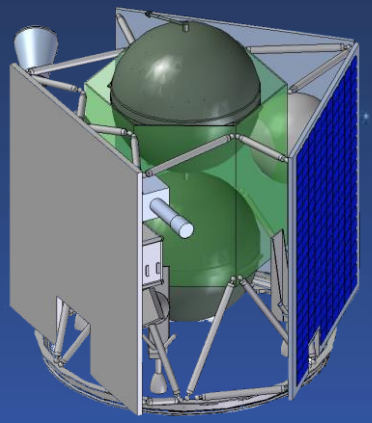
SURREY SATELLITE TECHNOLOGY LTD

Changing the economics of space

esmo

ESMO: An Inspirational Hands-On Space Education Project to the Moon





AMSAT-UK Colloquium
30 July 2011

esa

Univerza v Mariboru

TECHNISCHE UNIVERSITÄT MÜNCHEN

POLITEHNICA 1818

POLITECNICO MILANO

University of Ljubljana

AGH University of Science and Technology

Universidad de Vigo

THE UNIVERSITY OF WARWICK

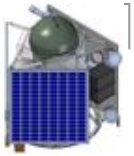
UNIVERSITY OF TARTU

University of Glasgow

CSL

University of Southampton

Background

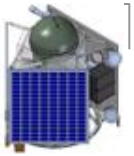


- European Student Moon Orbiter
  - 4th mission within ESA's Education Satellite Programme
- Builds upon experience gained with SSETI Express
  - a micro-satellite launched into LEO in 2005
- The YES2 tether experiment
  - launched into LEO on the Foton-M3 mission in 2007
- ESEO (European Student Earth Orbiter)
  - a micro-satellite planned for launch in 2012

Mission Objectives

- The mission objectives for the ESMO mission are as follows:
  - Launch the first lunar spacecraft to be designed, built and operated by students across ESA Member and Cooperating States
  - Place and operate the spacecraft in a lunar orbit
  - Acquire images of the Moon from a stable lunar orbit and transmit them back to Earth for education outreach purposes
  - Perform new measurements relevant to advanced technology demonstration, lunar science and exploration
- Launch early 2014

Educational Objectives



- Education and Outreach via a Hands On Space Mission, ESMO
  - ESMO is a unique and inspirational opportunity for university students
  - Provide a valuable and challenging hands-on space project experience
  - Prepare a well qualified workforce for future ESA missions

- It is a hands-on educational mission to the Moon. Goal is to learn by doing.

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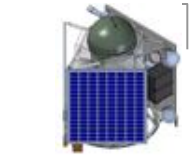
Technical Overview

Driving Mission Requirements



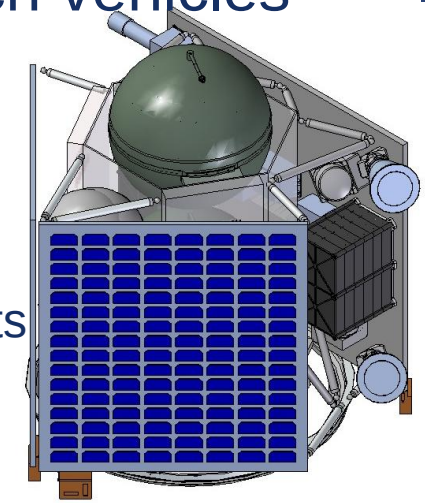
- Compatible with shared launch to GTO
  - To maximise launch opportunities

- Chemical propulsion system
  - To perform transfer from GTO to final Lunar Orbit
  - To minimise the time spent in the radiation belts
  - Makes use of ESA supplied flight spare hardware

- Selection of suitable final lunar orbit to support payloads and meet outreach objectives

Key Technical Drivers

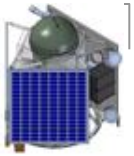
- Mass constrained largely due to two closely related factors:
  - ESA flight spare propulsion tanks (GIOVE-A2) are qualified to hold 54 kg propellant
  - Mission Delta-V reducing this as far as possible will allow use of the GIOVE-A2 propellant tanks
  - Key trade offs relating transfer trajectory, chemical propulsion system & AOCS performance & spacecraft mass
- Design for compatibility with a range of launch vehicles
- Cost & Schedule
  - Use of flight spares, donated and off the shelf items
  - ITAR- careful / minimal use of controlled components



Design Philosophy

- Mission designed so that where possible no credible single failure leads to loss of the mission
- Redundancy Strategy:
  - Hot redundancy - critical units
  - Cold redundancy - remaining units
  - Graceful degradation
  - Single string (if acceptable risk / no viable alternative)
- Failure Detection Identification and Recovery (FDIR)
  - For nominal operations a general fail safe strategy preferred to minimise complexity
  - For critical propulsive manoeuvres fail operational is targeted
- Margins:
  - Margins (power, mass, delta-V, propellant etc..) are added to all areas, both at equipment level and system level
  - Margins vary from 5-20% depending on development level

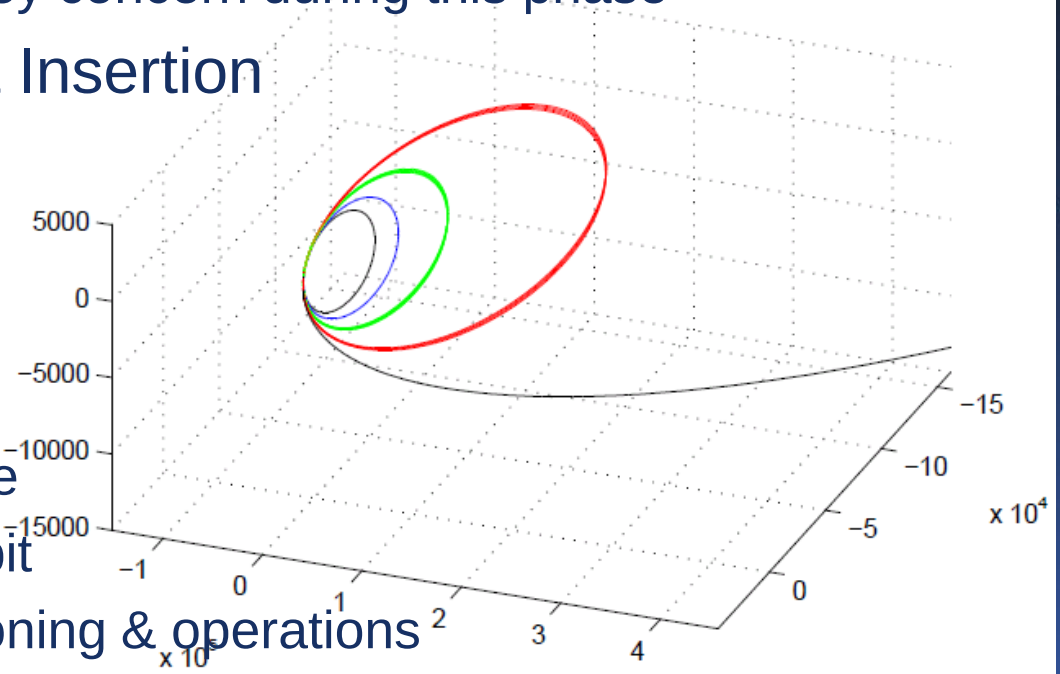
Payloads: Baseline & Backup



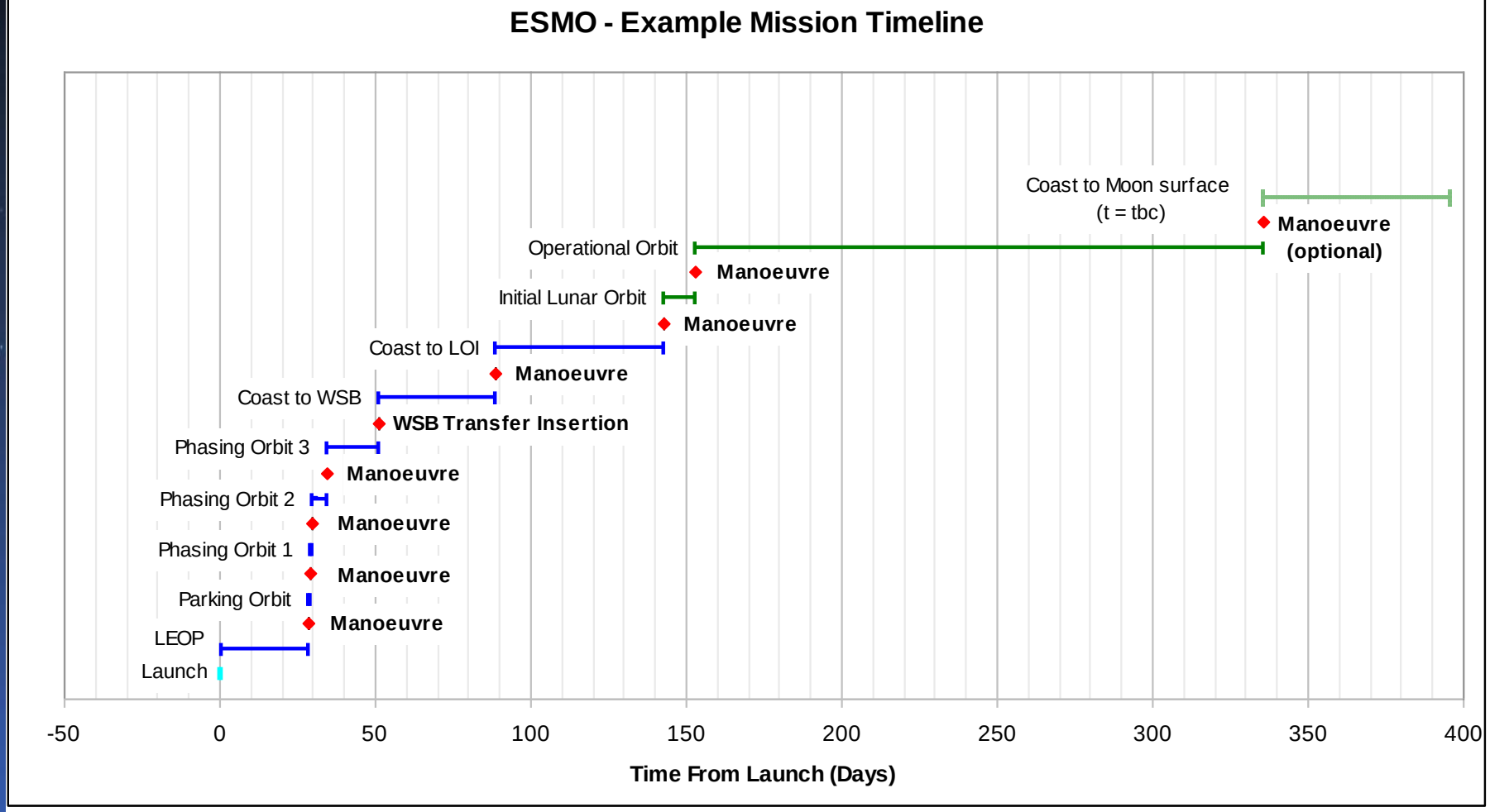
- Payloads currently being evaluated for accommodation requirements, readiness and suitability for ESMO. These include:
  - Narrow Angle Camera
    - Inclusion of an imaging camera required to meet outreach objectives
  - Radiation Monitor (Inclusion under assessment)
    - To measure the transfer and operational radiation environments
  - LunaNet (Inclusion under assessment)
    - Test the associated communication protocols required to support a lunar internet
  - Radar (Inclusion under assessment)
    - 1D Radar payload experiment. Other variations under investigation
  - MiWarS (Backup payload - inclusion under assessment)
    - Passive microwave radiometer providing details of the lunar subsurface
- Preliminary budgets assume
  - NAC, Radiation Monitor, Radar and LunaNet as baseline payload

Mission Phases Summary

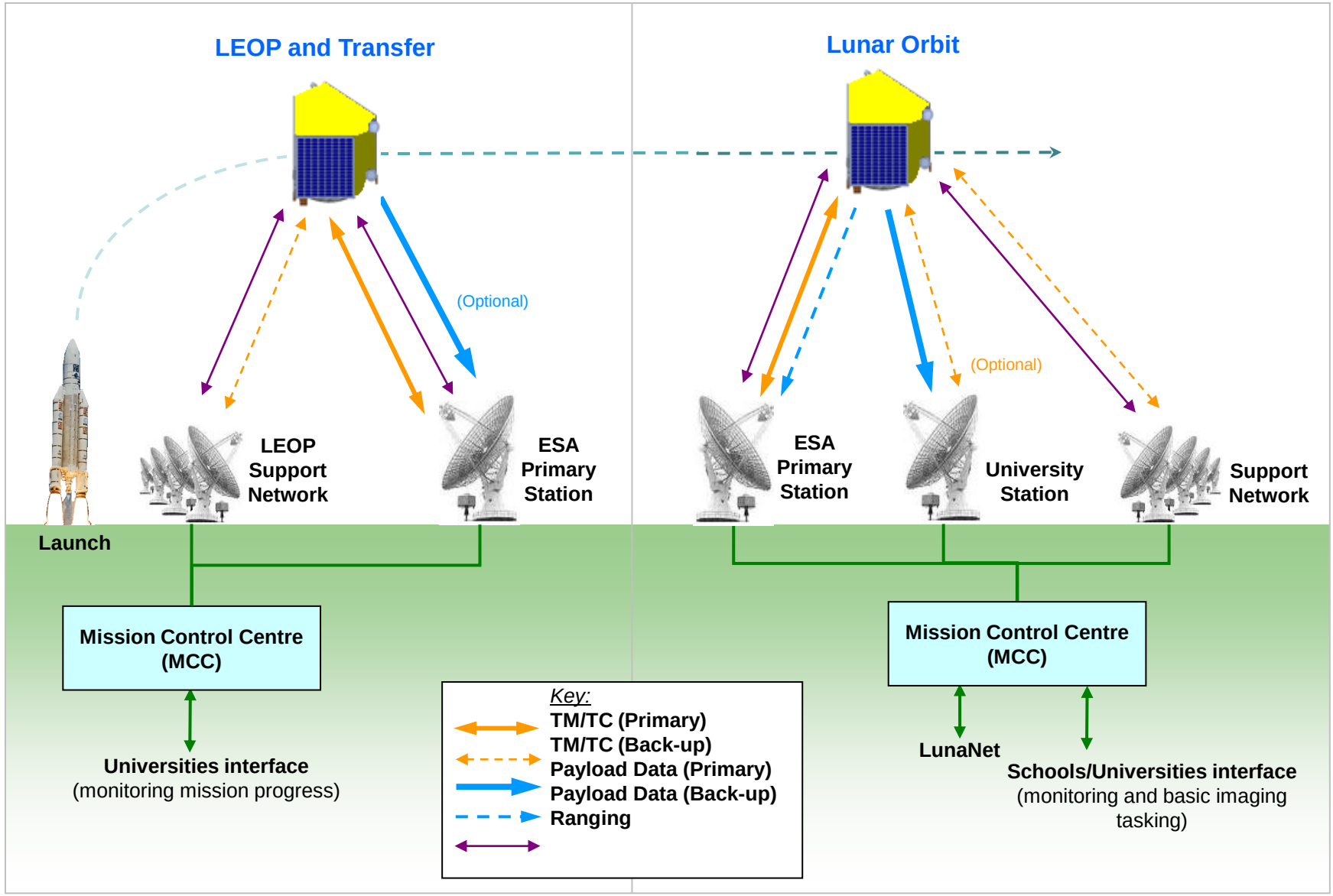
- LEOP/Commissioning
  - Baseline 1 month in GTO
  - Total Ionising Dose a key concern during this phase
- Transfer & Lunar Orbit Insertion
  - Apogee raising to WSB
  - Navigation/Ranging
  - Capture into lunar orbit
- Operational Orbit
  - 6 months target lifetime
  - Highly elliptic Lunar orbit
  - Full payload commissioning & operations
- End of Life
  - Natural orbit decay until surface impact



Transfer Timeline



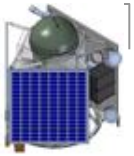
Concept of Operations



Failure Detection Isolation & Recovery

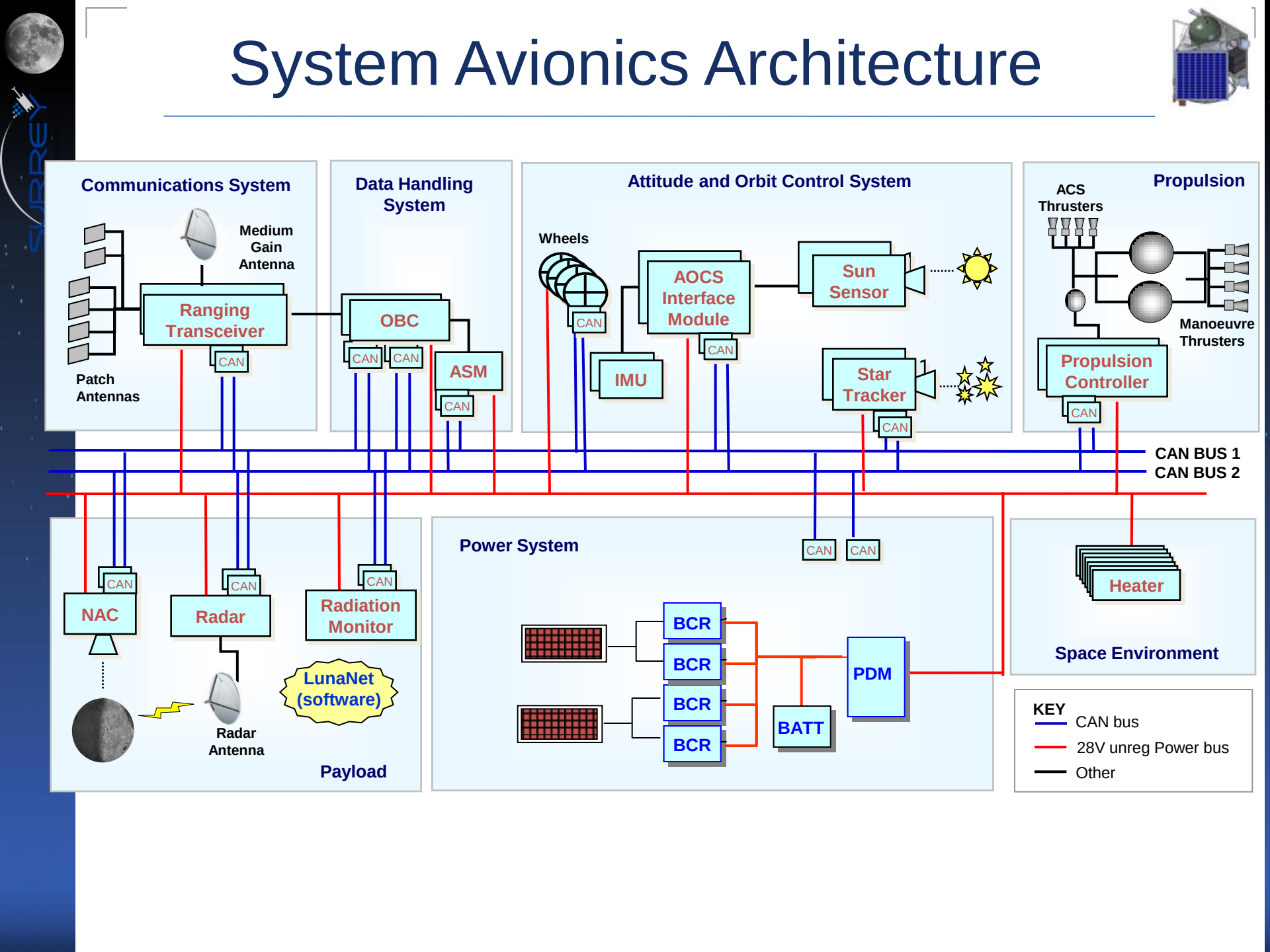
- Based on GIOVE-A concept
  - Timings and failure scenarios used as starting point
- Currently split into 5 scenarios
  - LEOP
    - Automatic start up required
    - Mode handling launch into eclipse being developed
  - Nominal
    - Spacecraft maintains sun pointing at all times
    - Fail safe
    - Nominal & safe mode are the same
  - Off-pointing
    - Payload operations in lunar orbit
    - High rate downlink
    - Fail safe
  - Critical Manoeuvre
    - Target to fail operational
  - Non-critical manoeuvre
    - Fail safe

Spacecraft Overview

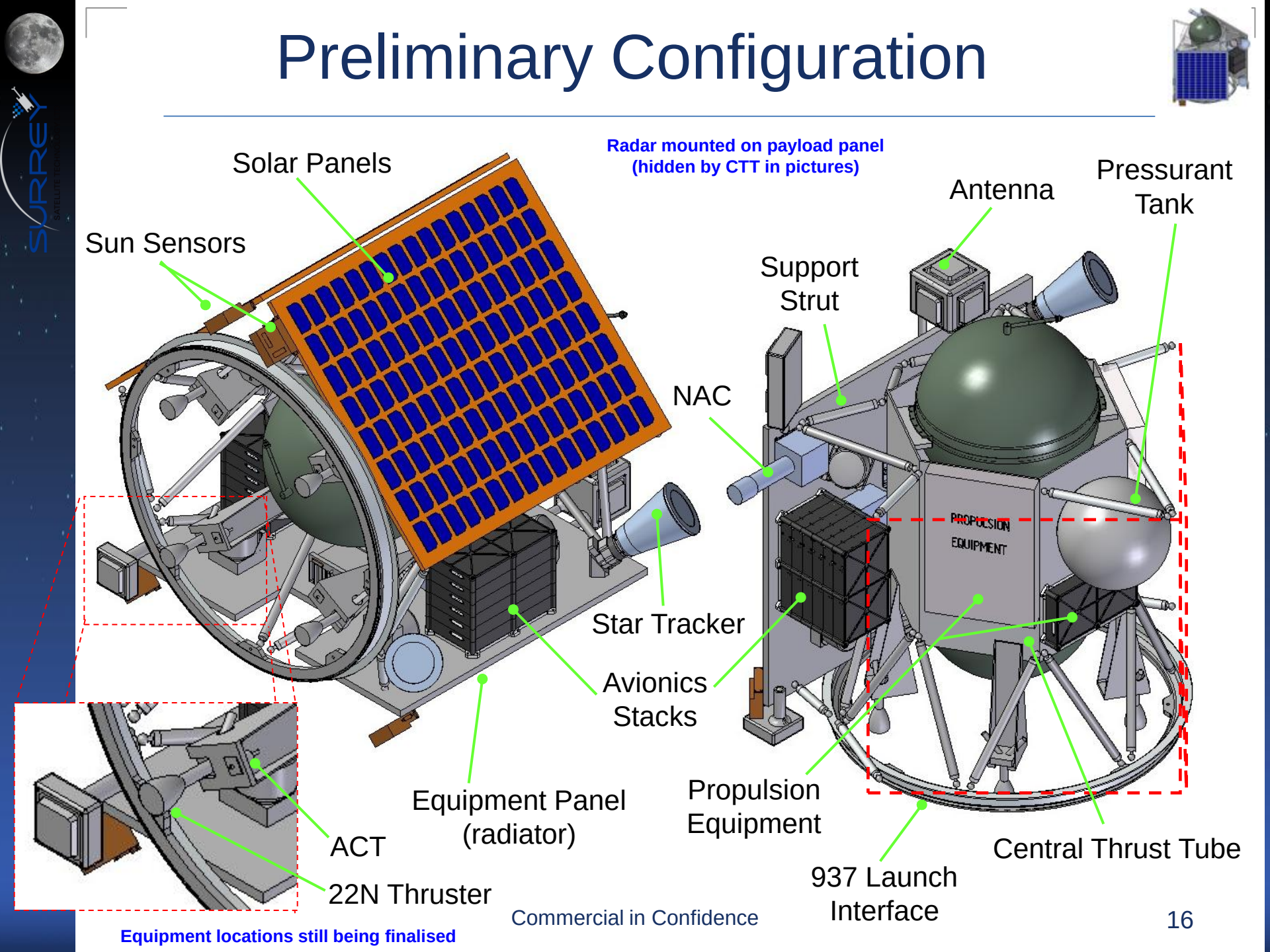


- ESMO Preliminary Platform Design:
  - Low mass “open” structure
    - central thrust tube, struts and panels
  - 265kg max mass, 2-5kg payload capability….
  - 2 x body mounted solar arrays, 28V (reg/ unreg) bus
  - Bi-propellant primary propulsion system
    - 2 x flight spare propellant tanks
  - 3 Axis control AOCS
    - Sun sensors, IMUs, star trackers, reaction wheels, 4 x cold gas thrusters, AOCS interface module
  - S-Band communications system
    - 6 x low gain antennas, 1 /2 flight spare medium gain antenna(s)
  - OBDH system
    - 2 OBC’s, dual redundant data bus (CAN), attitude safety module
  - Thermal control system, passive with heaters

System Avionics Architecture



Preliminary Configuration

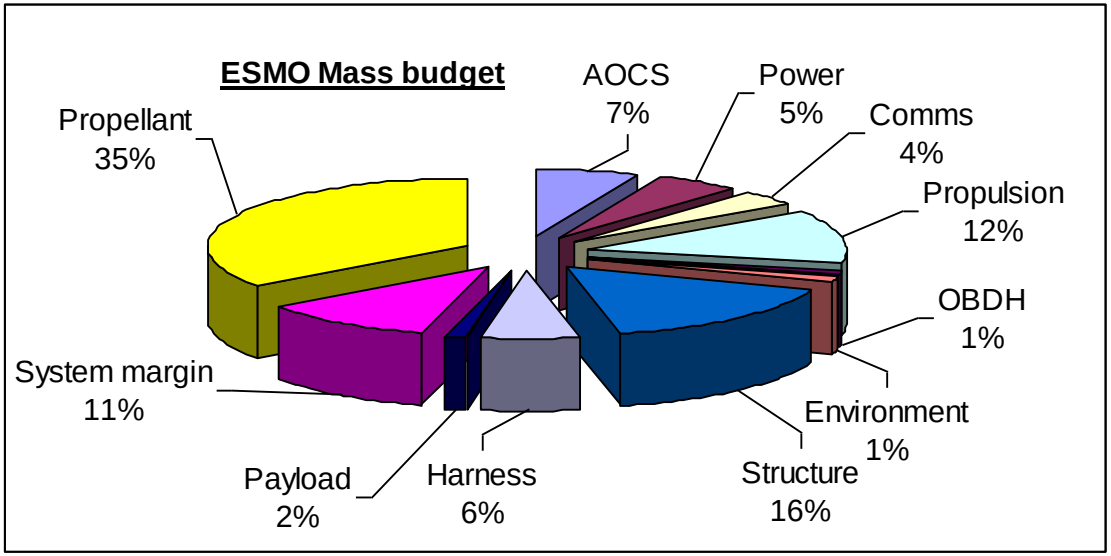


Equipment locations still being finalised

Mass Budget

- Maximum wet mass for ESMO is 265kg

Sub-system	Total mass (kg)
AOCS	17.0
Power	13.4
Comms	10.6
Propulsion	32.5
OBDH	3.0
Environment	3.6
Structure	42.0
Harness	15.6
Payload	4.2
Sub-system total	142.1
System margin	28.4
Dry mass	170.5
Propellant	92.8
Launch mass	263.3



MMH	37.40	kg
NTO	52.36	kg
ACS	3.02	kg

Upper limit of qualified tank capacity is 54kg

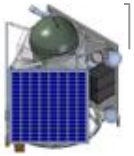
This limits maximum mass of spacecraft to ~265kg

Power Budget

- Scenarios
  - Various scenarios are identified to find worst case sizing cases for battery, arrays etc.
- Margins used
  - Equipment level: New development, Modified, Rebuild (20%, 10%, 5%)
  - System level (20%)

	LEOP/ Deployment	Sunlight Manoeuvre	Eclipse Manoeuvre	Coast/Cruise	Nominal Lunar Operations	Lunar Orbit Eclipse
AOCS	**17.7**	**33.0**	**33.0**	**25.4**	**25.4**	**25.4**
Power	**7.2**	**7.2**	**7.2**	**7.2**	**7.2**	**7.2**
Communications	**19.8**	**37.2**	**37.2**	**20.7**	**20.6**	**19.2**
Propulsion	**2.2**	**86.3**	**86.3**	**10.4**	**10.4**	**10.4**
OBDH	**20.5**	**24.0**	**24.0**	**21.6**	**21.6**	**21.6**
Thermal	**22.7**	**24.1**	**42.4**	**24.1**	**24.1**	**42.4**
NAC	**0**	**0**	**0**	**0**	**0.5**	**0**
RMP	**0**	**0**	**0**	**0**	**0.2**	**0**
Radar	**0**	**0**	**0**	**0**	**0.5**	**0**
LunaNet	**0**	**0**	**0**	**0**	**0**	**0**
Subsystem Total	**87.1**	**211.8**	**230.1**	**109.4**	**110.5**	**126.2**
System Margin	**20%**	**20%**	**20%**	**20%**	**20%**	**20%**
Total Power (W)	**104.5**	**254.1**	**276.1**	**131.3**	**132.6**	**151.4**

Link Budgets Summary



- Budgets based upon best case antenna gains presented
  - Spacecraft antenna pattern may have nulls, leading to loss of coverage at the furthest points
- Downlink
  - Near omni-directional coverage for TM downlink in all mission phases excluding WSB region. Here there may be significant nulls leading to limited coverage
- Uplink
  - Near-omni directional coverage for TC uplink is possible in all mission phases
- Additional Risk mitigation
  - MGA directional downlink could be used at largest Earth-spacecraft distances to improve downlink data rate
  - Bigger dishes also being investigated to support...

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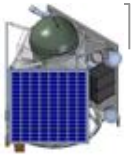
Programme Overview

Roles & Responsibilities 1/2

- ESA Education Office – ESMO Customer
  - Providing a flight opportunity to the Moon
  - Technical support throughout the programme at reviews & workshops
  - Flight spare hardware provided by ESA where possible
    - GIOVE-A2 propellant tanks, Smart-1 / GOCE medium gain antenna, pressure regulators, heaters, thermostats, solar cells..
    - Primary ground station provided by ESA at Villafranca
  - ESA and SSTL working closely as partners

- Surrey Satellite Technology Limited
  - ESMO Prime Contractor on behalf of ESA
  - Leading the systems engineering
  - Providing mentoring & internships to the university teams
  - SSTL and NoU working closely as partners

Roles & Responsibilities 2/2



- Network of Universities (NoU)
  - Each university represented by professional academic staff & a student team
  - 20 universities from 11 countries
    - From ESA Member States & PECS Countries
  - Responsible for the design, development & testing of flight worthy spacecraft units / subsystems required for ESMO
  - Universities providing flight and test hardware/software for all aspects of the mission
  - All teams also have to invest time to find additional funding, sponsorship, donations and support
    - Preparation for work in the space industry!
    - Builds local and regional industrial links for universities
  - Professors are key to ensuring they have a mechanism for providing continuity into the project across academic years

The ESMO Network of Universities

University	Country	Responsibilities
University of Liège	Belgium	Narrow angle camera payload
Czech Technical University	Czech Republic	Attitude interface module
University of Tartu	Estonia	Assembly, integration & verification & satellite operation
SUPAERO	France	Star Tracker
University of Stuttgart	Germany	Propulsion system - gas feed
Technical University of Munich	Germany	LunaNet payload & ground segment
Politecnico di Milano	Italy	Attitude and orbit determination and control system
Politecnico di Milano	Italy	Propulsion system - liquid feed
University of L'Aquila	Italy	MiWars – back-up payload
Warsaw University of Technology	Poland	Configuration
Warsaw University of Technology	Poland	Thermal control subsystem
Wroclaw University of Technology	Poland	Communications system
AGH University of Science & Technology	Poland	Space environment & effects analysis
Politehnica University of Bucharest	Romania	Attitude and orbit determination and control system
Politehnica University of Bucharest	Romania	Structure
University of Bucharest	Romania	Radiation monitor payload
University of Ljubljana	Slovenia	Simulator
University of Ljubljana	Slovenia	Radar payload
University of Maribor	Slovenia	On-board data handling
University of Oviedo	Spain	Harness
University of Vigo	Spain	Ground station
University of Strathclyde	UK	Mission analysis and flight dynamics
University of Southampton	UK	Systems engineering
University of Warwick	UK	Power subsystem

Programme Overview

Customer: ESA

ESMO Project Management

System Engineering + AIT

Requirements Consolidation

Mission & System Design

Platform Subsystems Design *

Payload Design *

Ground Segment Design *

Manufacture & Test*

Launcher Procurement

Acceptance into AIV by SSTL

Satellite Integration

Acceptance by ESA

S/ C System Tests & EVT

Integration into Launch Vehicle

Operations

LEOP

KO SRR SDR PDR CDR QR FAR LRR

Phase B2 Phase C Phase D Phase E1 Phase E2

N.B Milestone timeline is not to scale

* hardware , software , SQM & relevant GSE

KEY

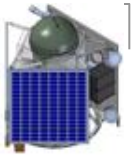
NoU Led with Internships + SSTL mentoring

SSTL Led with NoU support + Internships

SSTL only

ESA

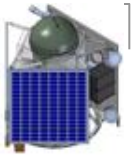
Project Status



- ✓ System Requirements Review (SRR) - complete
  - ✓ Baseline mission and system requirements agreed
- ✓ System Definition Review (SDR) – complete
  - ✓ Consolidation of the mission, system and programmatic baseline of the project
- Preliminary Design Phase Work
  - Consolidation of the network of universities and work packages
  - Derivation and consolidation of all requirements down to unit-level
  - Preliminary definition of the technical baseline; space & ground segment definition, system budgets and interfaces down to unit-level
  - Design description & justification against the requirements
  - Design development and verification plans for Phases C/D.
- Preliminary Design Review (PDR) - Kicked off March 28th 2011
  - PDR Co-location held at ESTEC in May 2011
  - Currently in PDR closeout phase

- Critical Design Review – May 2012
- Qualification Review – January 2013
- Flight Acceptance Review – January 2014
  - TBC - ESA currently in discussions with Launch Agencies

Challenges & Approaches



- Applying small satellite design philosophy to a wide geographic spread of teams
- Delivering a space mission on academic schedules
- The numerous technical challenges of getting to the Moon…

- ✓ Regular & open communications are vital
- ✓ Rolling training/ mentoring, technical workshops & internships
- ✓ Role of professors & professional university support is critical
  - Ownership, assembling teams with the right level of academic support, motivating the teams & ensuring continuity between academic years
- ✓ Teaming with excellent academic institutions with core skills that can do the job
- ✓ Industrial mentoring from small satellite mission experts, SSTL
- ✓ Space institutional mentoring from European Space Agency experts
- ✓ Enabled via close partnership between ESA, SSTL and the network of universities

Opportunities

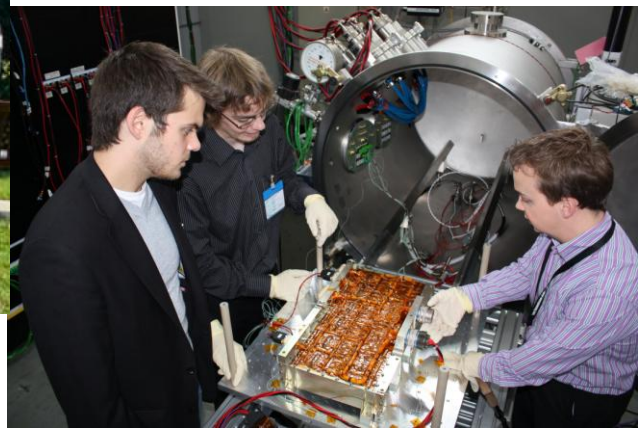
- Bring on board industrial sponsors and relevant experts to enhance and enrich the programme
  - ✓ Widen the education and outreach impacts of the programme
  - ✓ Improve the product
  - ✓ Further maximise the scientific, demonstration & exploration potential of ESMO within the mission constraints
    - i.e. Without impacting the design significantly!!
  - ✓ Some scope to include additional technologies, experiments

- This is about the journey as well as the end-goal

Acknowledgements

- Many thanks to :
  - The ESMO network of universities & SSTL team for their continued hard work and enthusiasm
  - ESA, especially Dr Roger Walker & Christiane Mueller, for their support and team work
  - Our project sponsors for their enabling inputs and support

ESMO Team at Phase B Kick Off Workshop at SSTL, Oct 2009



University of Warwick Students at ABSL

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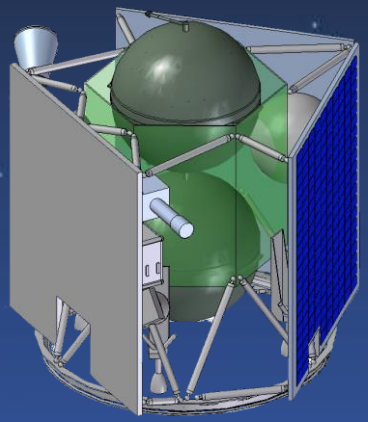

Thank you!

Any Questions?