STE-QUEST Mission Design Overview and Status

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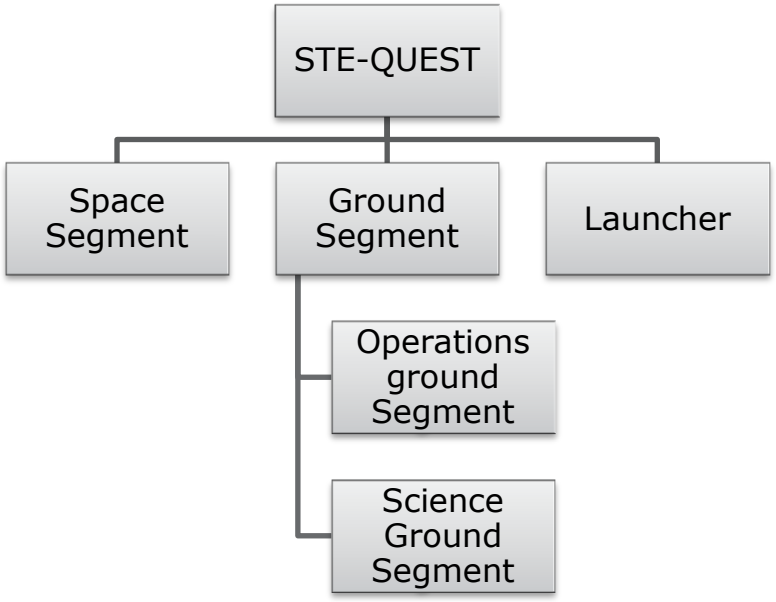
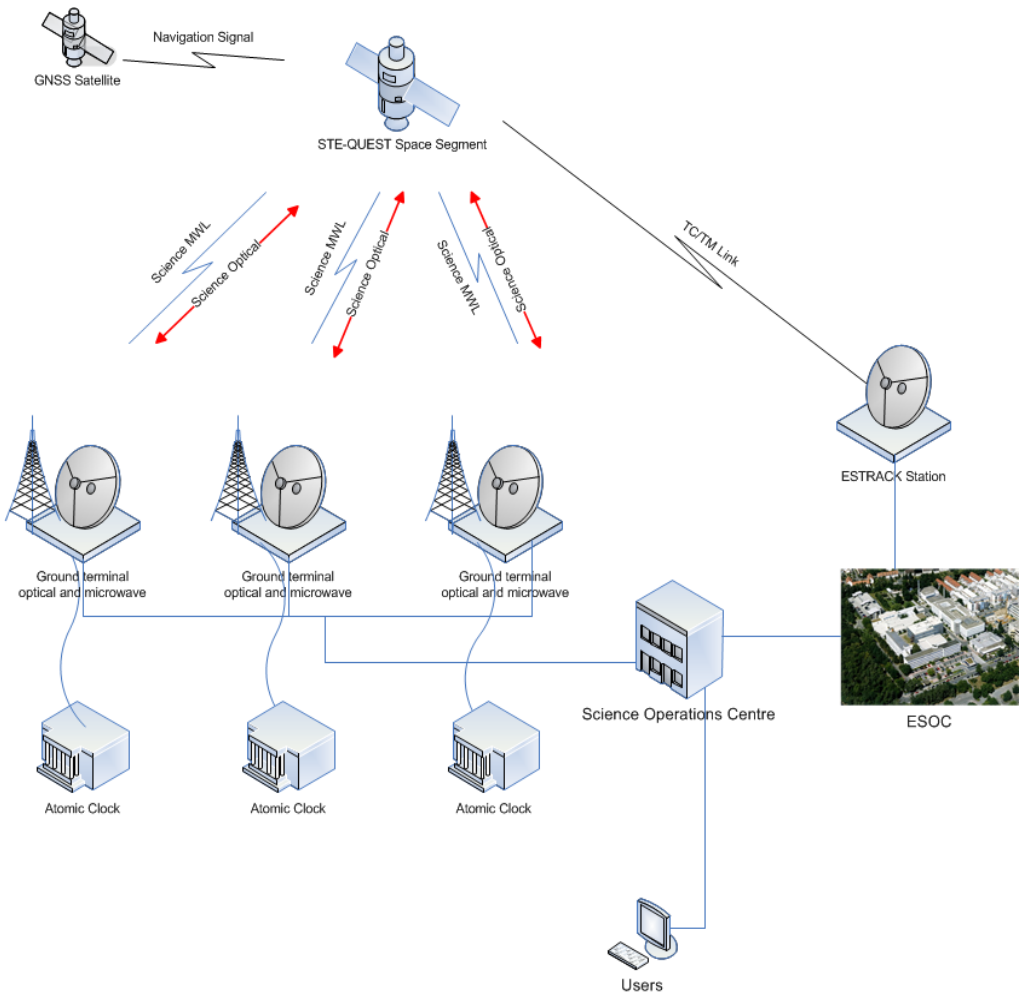
Mission Concept

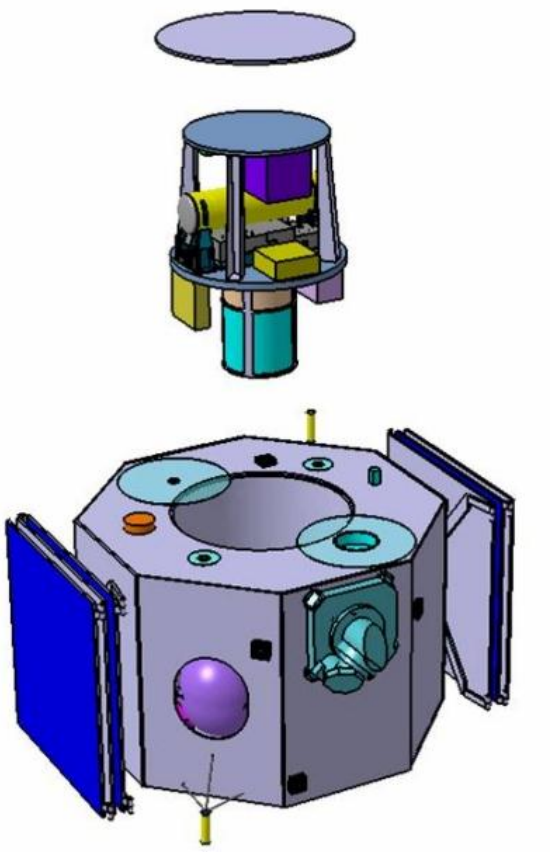




Spacecraft Key Properties

- Launch Mass: ~2100 kg
- Electrical Power: ~2 kW
- Instrument mass: ~450 kg, power: ~1040W
- 3-axis stabilized S/C, cold gas attitude control (tbc)
- Power: GaAs solar array, Batteries
- Thermal: Radiators, payload cooling via heat pipes
- X-band TT&C (~3-8 Gbit/orbit)

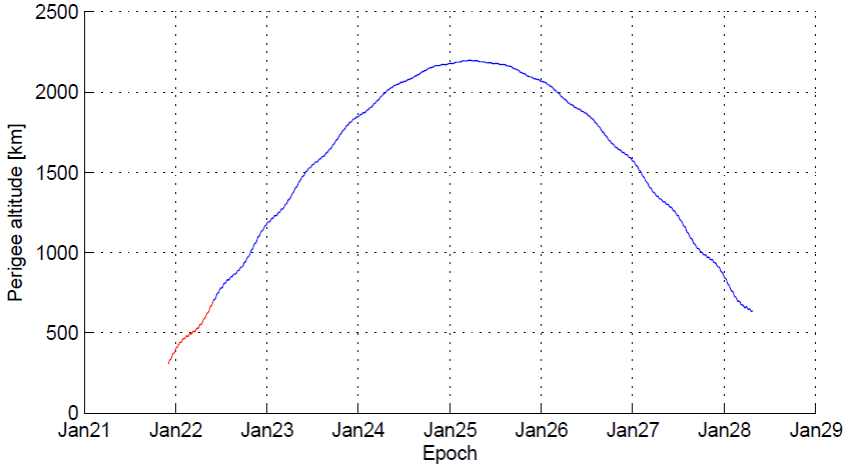
- Mission Lifetime: 5 years
- Challenges: P/L thermal control, radiation, P/L accommodation



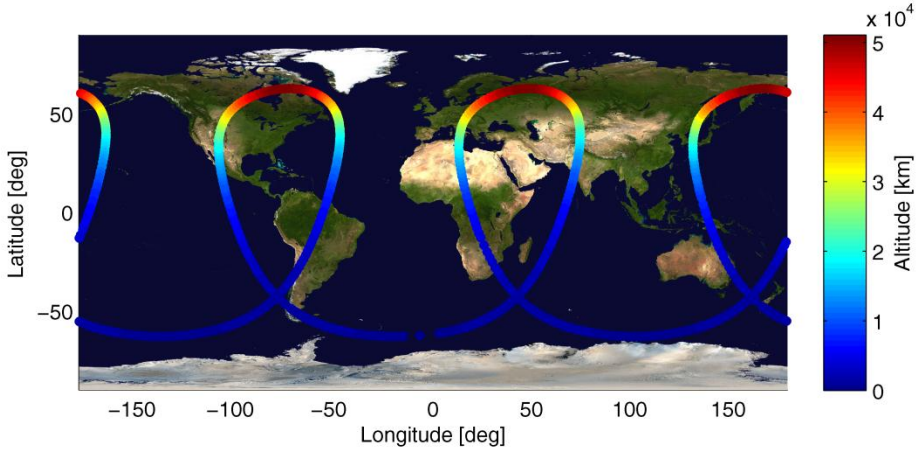
CDF configuration

STE-QUEST Baseline Mission Profile

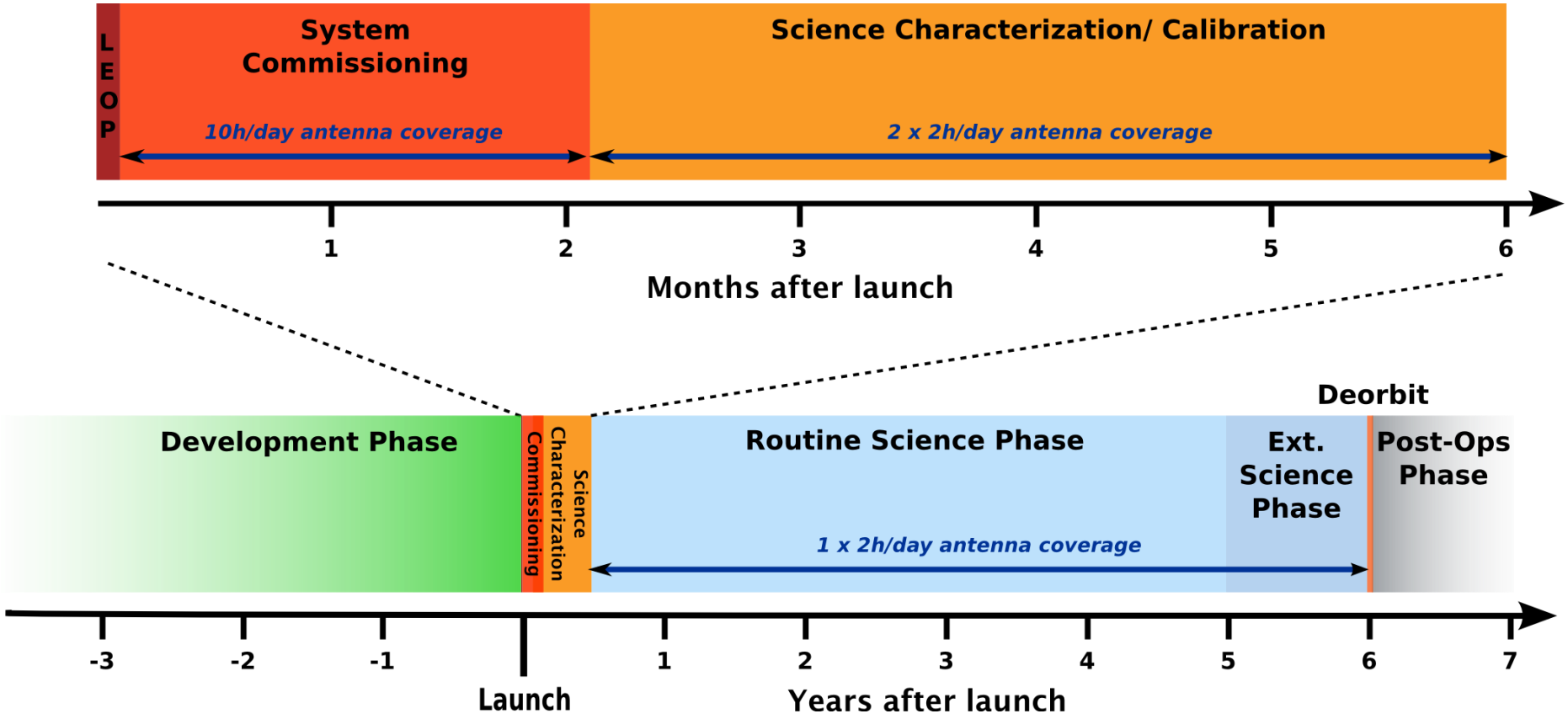
- Launch with Soyuz/Fregat from Kourou
- Highly Elliptical Orbit (HEO): ~700 x 51000 km altitude
- Perigee altitude evolving 700 -> 2100 -> 700 km
- Apogee locations for maximum common visibility of ground terminals
- Exact orbit parameters dependent on launch date



Parameter	Value
Reference Epoch	01-Jun-2022 20:11:02
Semi-major axis	32090.9272km
Eccentricity	0.77943
Inclination	62.59°
Right ascension of ascending node (RAAN)	265.37°
Argument of Perigee	271.95°
True Anomaly	28.65°
Initial drift in RAAN	-0.10519°/day



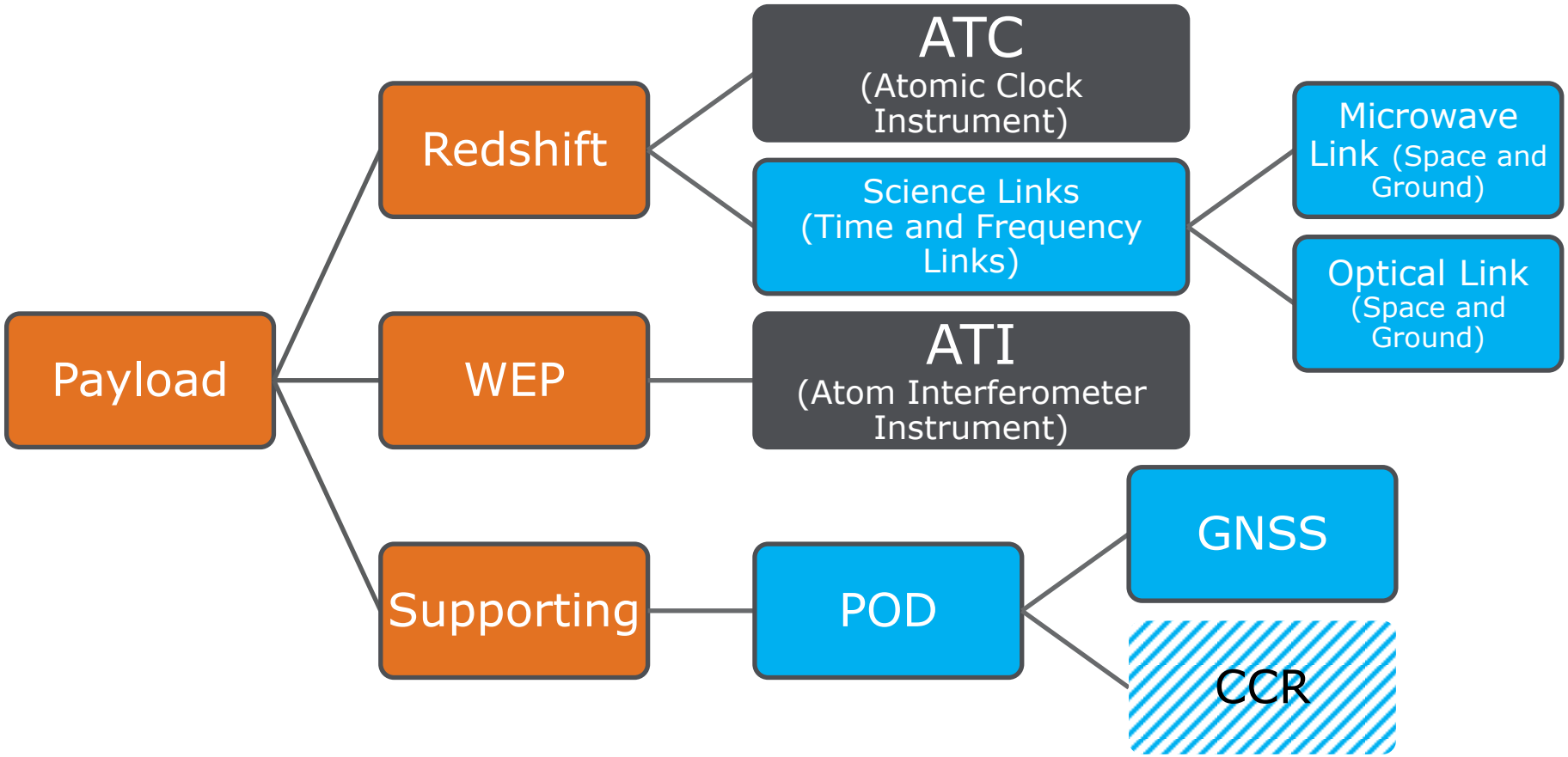
Mission Phases



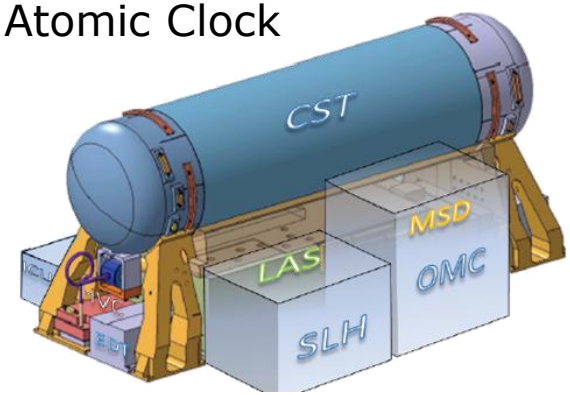
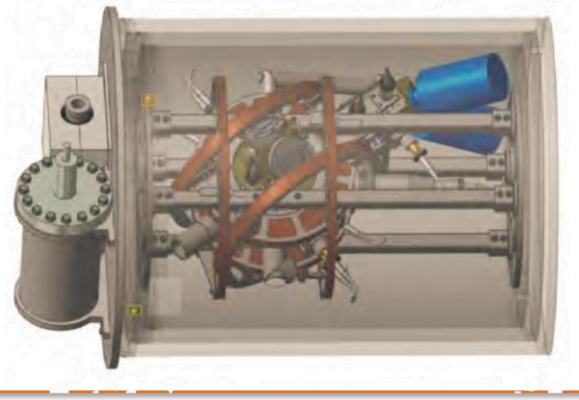
Design Constraints (non-exhaustive)

- Programmatic Launcher choice:
  - Launch mass constraint
  - Injection constraints -> orbit limitations (launch site, safety)
- Link availability:
  - Orbit design
  - Pointing
- Payload requirements:
  - Attitude control
  - Power/Thermal
- Policies/Regulations:
  - Active de-orbiting (Space Debris mitigation)
  - Link design (flux densities, bandwidths, frequencies)

Payload Architecture/Responsibilities



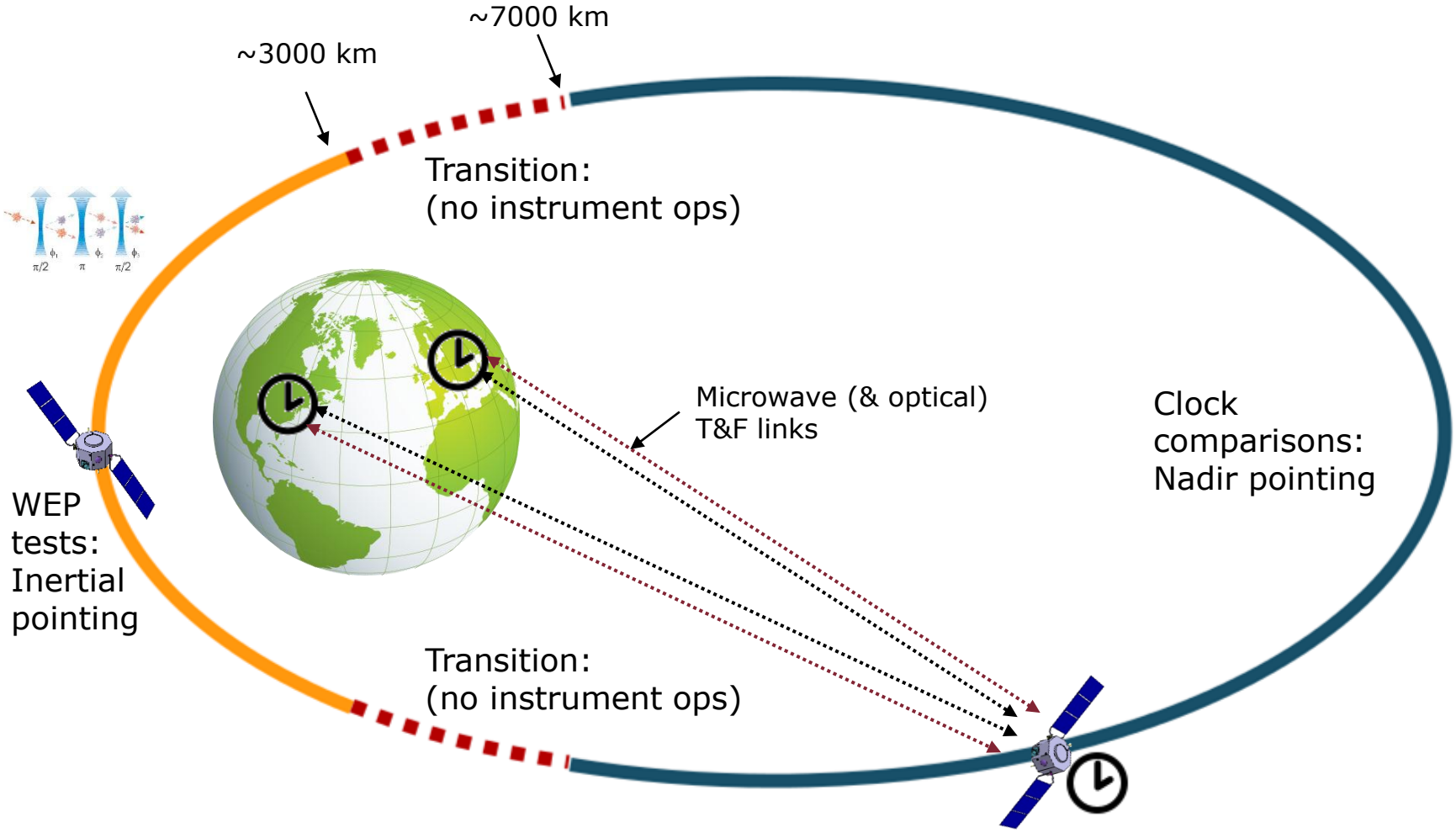
Instruments Overview

Instrument	Acronym	High Level Description
Atomic Clock 	ATC	Cold atom microwave clock with optical oscillator for short term performance.
Atom Interferometer 	ATI	Dual-species Rb85, Rb87 cold atom interferometer for differential acceleration measurements.

Additional Payload Items

Time and Frequency Links	High Level Description
Microwave Links	X, K(a) band links Up to four links w/ ground simultaneously Up to 10 W Tx power on board Three (min) ground terminals connected to metrology institutes
Optical Links	2 Optical Communication Terminals on board Up to two links simultaneously Three (min) ground terminals
Instruments	**High Level Description**
GNSS	GNSS receiver for POD in post-processing and for quick-look orbitography data. Based on multi-constellation designs.
Radiation Monitor	Verification of radiation models, possible warning system for radiation events / trace to effects.
Shielding	**High Level Description**
Spacecraft	S/C structure acts as shielding (location dependent)
Equipment Level	Box shielding, equipment box acts as shield
Component Level	Dedicated component shielding for sensitive components
Part Level	Spot shielding, highly specific

Instrument Operations



Radiation Environment

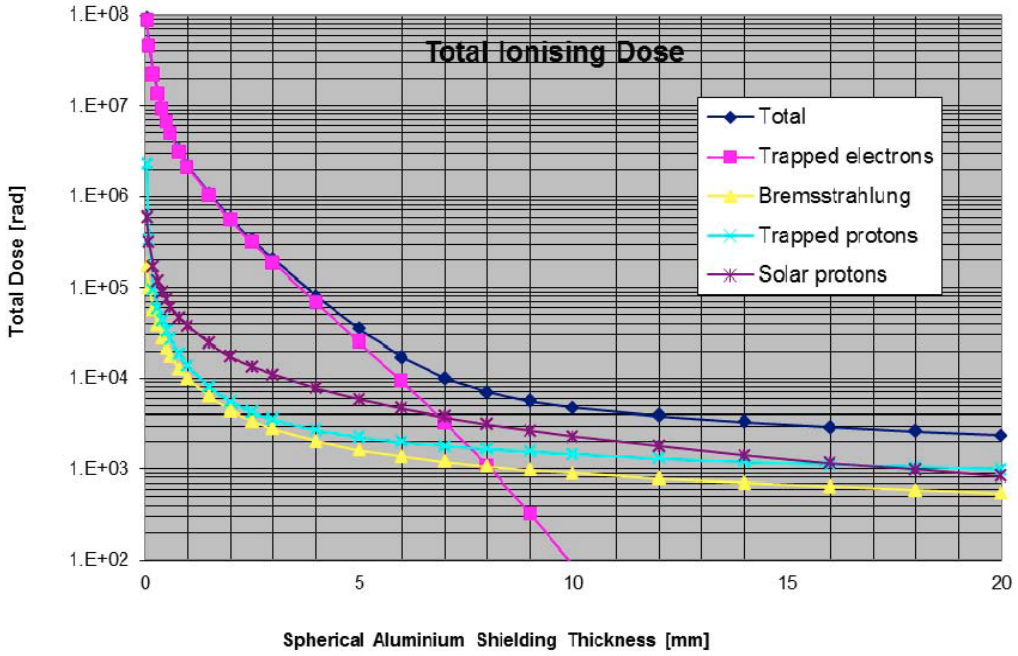
- Major Influences:
  - Total Ionizing Dose: Trapped Electrons (Electronics, material degradation, internal charging (-> fields)
  - Displacement Damage: (Solar) Protons (optical/opto-electronics components)
- STE-QUEST Environment:
  - Two belt-crossings per orbit
  - Environment dominated by electrons (comparable to GEO doses, efficient shielding)
  - Proton environment higher than for GEO (delta-qualification for some parts)

	Parameter
Electronic component degradation	Total ionizing dose.
Material degradation	"
Material degradation (bulk damage)	Non-ionizing dose (NIEL).
CCD, sensor and opto-electronic component degradation	NIEL
Solar cell degradation	NIEL & *equivalent fluence.*
Single-event upset, latch-up, etc.	LET spectra (ions); proton energy spectra; explicit SEU/SEL rate of devices.
Sensor interference (background signals)	Flux above above energy threshold and/or flux threshold; explicit background rate.
Internal electrostatic charging	Electron flux and fluence; dielectric E-field.

Total Dose

Shielding Thickness [mm]	Total ionising dose in Si for Spherical Al Shielding [rad]				
	Total	Trapped Electrons	Brems strahlung	Trapped Protons	Solar Protons
3	2.01E+05	1.84E+05	2.75E+03	3.52E+03	1.09E+04
4	7.95E+04	6.71E+04	2.02E+03	2.69E+03	7.66E+03
5	3.47E+04	2.51E+04	1.62E+03	2.24E+03	5.76E+03
6	1.72E+04	9.25E+03	1.37E+03	1.98E+03	4.59E+03
7	9.97E+03	3.27E+03	1.19E+03	1.79E+03	3.72E+03
8	6.89E+03	1.07E+03	1.06E+03	1.65E+03	3.10E+03
9	5.50E+03	3.21E+02	9.67E+02	1.55E+03	2.66E+03
10	4.71E+03	8.67E+01	8.94E+02	1.45E+03	2.28E+03

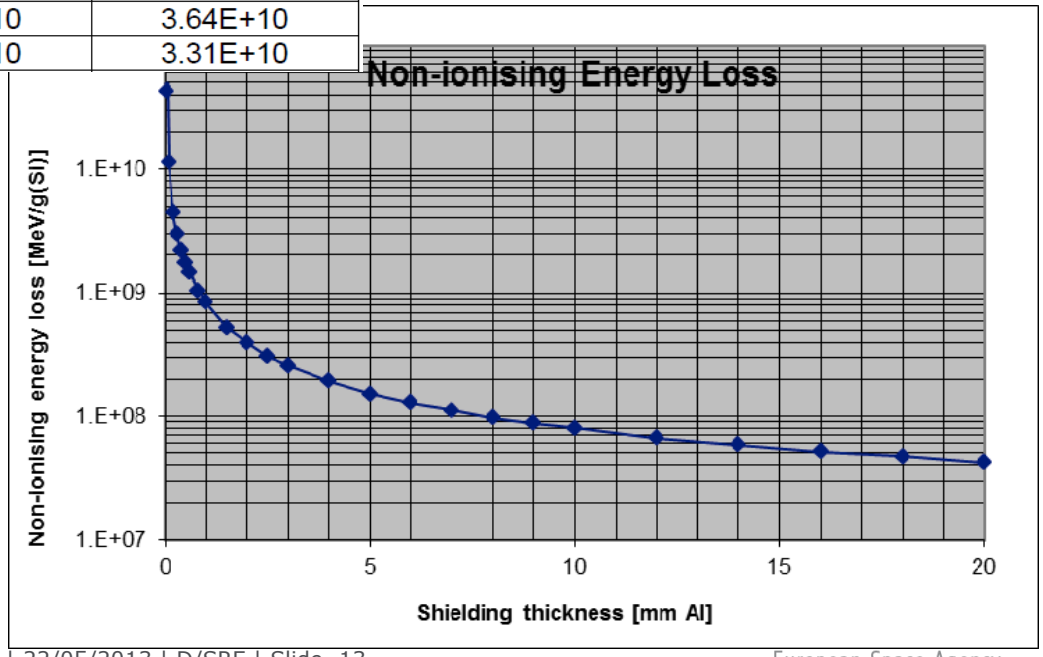
- Shielding thickness by s/c structure between 3 and 10 mm equivalent Al-sphere
- Can be handled efficiently on S/C side (GEO-qualified components)
- Payload design to use qualified parts as much as possible



Non-Ionizing

Aluminium shielding thickness [mm]	Non ionising energy loss and equivalent proton fluence			
	Energy loss [MeV/g(Si)]	Eq 10MeV Proton fluence [#/cm2]	Eq 60MeV Proton fluence [#/cm2]	Eq 200MeV Proton fluence [#/cm2]
3	2.58E+08	3.75E+10	7.48E+10	1.08E+11
4	1.91E+08	2.77E+10	5.54E+10	7.98E+10
5	1.50E+08	2.18E+10	4.35E+10	6.26E+10
6	1.29E+08	1.86E+10	3.72E+10	5.36E+10
7	1.12E+08	1.62E+10	3.23E+10	4.65E+10
8	9.66E+07	1.40E+10	2.80E+10	4.02E+10
9	8.74E+07	1.27E+10	2.53E+10	3.64E+10
10	7.94E+07	1.15E+10	2.30E+10	3.31E+10

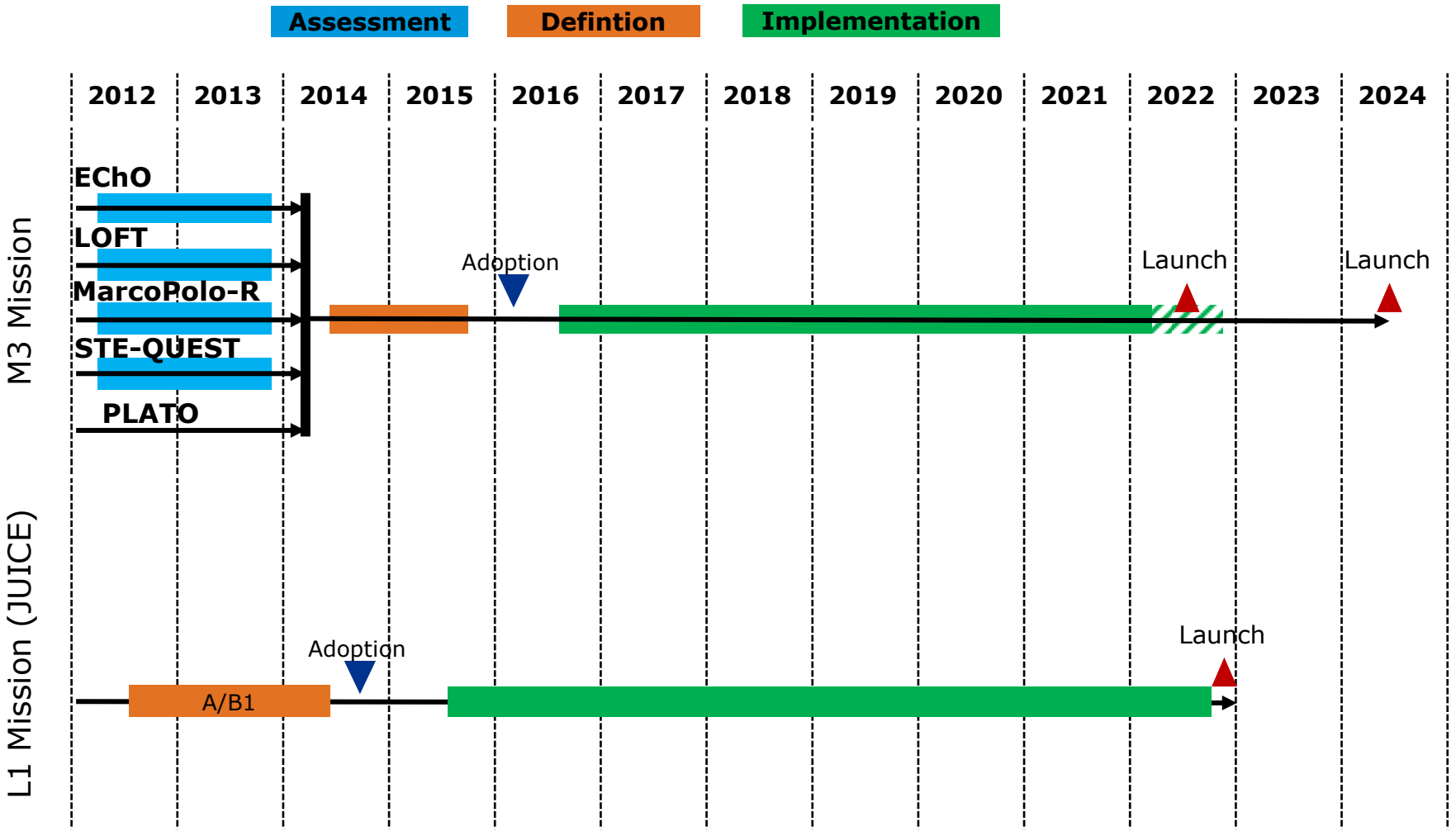
- Shielding thickness by s/c structure between 3 and 10 mm equivalent Al-sphere
- Proton environment relatively high, of concern for optical components, fibers.
- Main problem for components located outside/close to outer walls



Outlook & Programmatics

- Industrial Studies: Completed by July 2013
- Instrument Studies: Completed by September 2013
- Preliminary Requirements Review: October/November 2013
  - Technical and Programmatic Assessment
  - Outcome supports the M3 mission down-selection by SPC in February 2014

Cosmic Vision Implementation Schedule (Tentative)



Tentative Near-Term Mission Planning