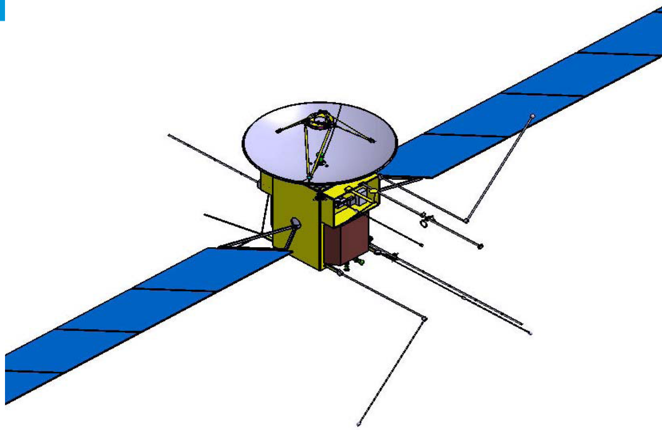
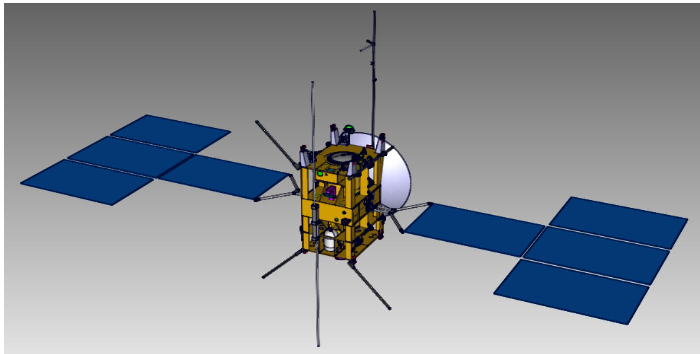
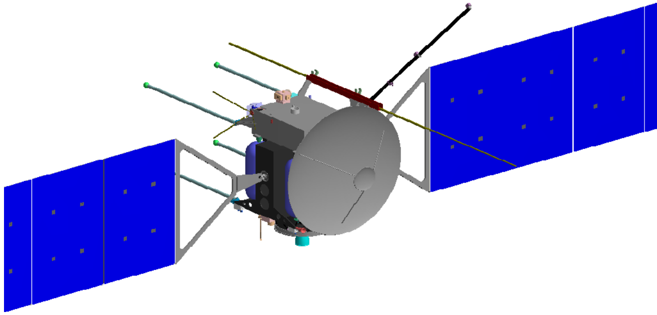
JUICE/Laplace Mission Summary & Status







C. Erd
JUICE Instrument WS, Darmstadt
9/11/2011

Activities during the Reformulation Phase

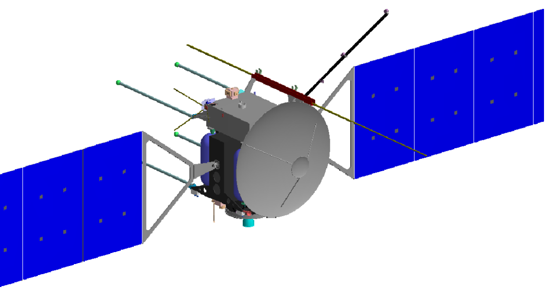
1. Feasible JGO s/c as a starting point
    a. no re-design of s/c necessary
    b. Changes driven by changes of mission profile (Europa flybys, Jupiter high latitude)
    c. Model payload left unchanged
2. Review and release of updated radiation model used for
    a. Comparison with JGO baseline
    b. Evaluation of impact of Europa flyby scenario
3. More detailed simulation of radiation exposure
    a. Shielding approach, background estimates
    b. Evaluation of possible solar array degradation
4. Continuation of technology developments and preparations

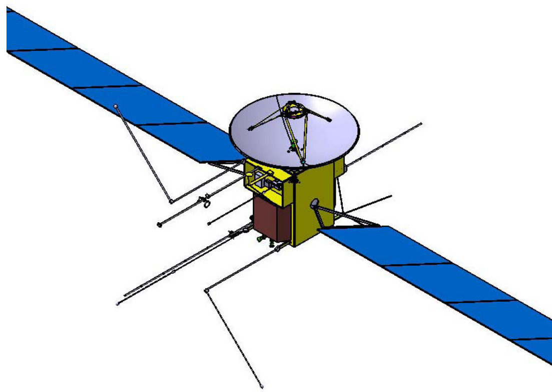
From JGO to JUICE: Changes

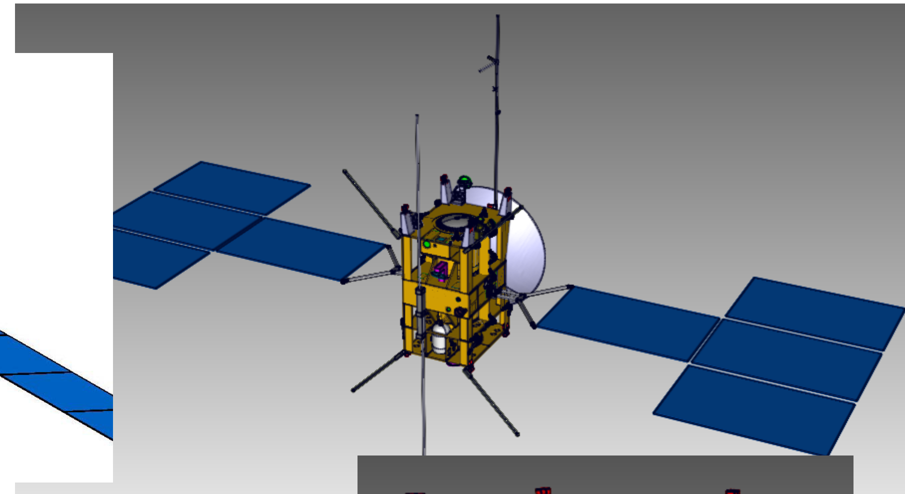
1. No changes to spacecraft configuration and model payload
2. Changed mission profile
3. Updated radiation environment
4. Planetary protection
5. Planned next steps and tentative schedule

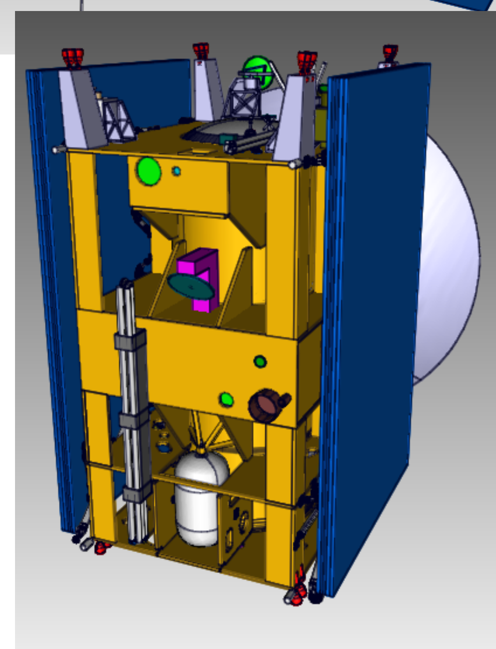
Baseline Spacecraft

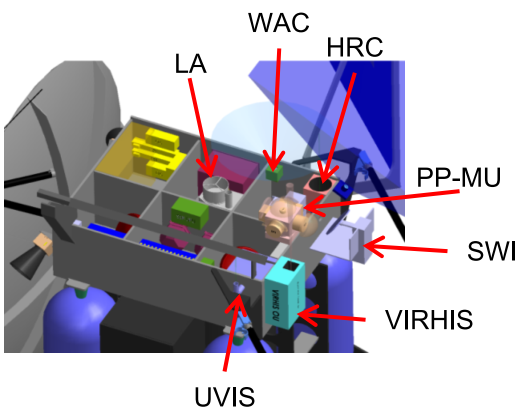
Spacecraft Configuration – Unchanged

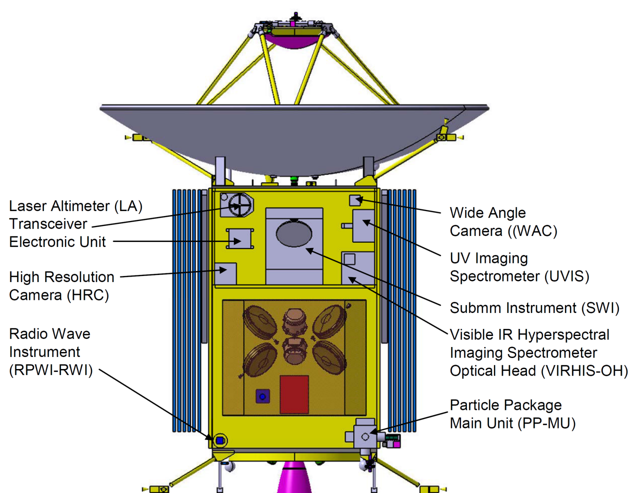












JUICE Model Instruments

Total mass: 104 kg

Imaging	
Narrow Angle Camera (NAC)	10 kg
Wide Angle Camera (WAC)	4.5 kg

In situ Fields and Particles	
Magnetometer (MAG)	1.8 kg
Radio and Plasma Wave Instr. (RPWI)	11.2 kg
Particle and Plasma Instr.— Ion Neutral Mass Spectr. (PPI-INMS)	18.2 kg

Spectroscopy	
Visible Infrared Hyperspectral Imaging Spectrometer (VIRHIS)	17 kg
UV Imaging Spectrometer (UVIS)	6.5 kg
Sub-mm Wave Instrument (SWI)	9.7 kg

Sounders & Radio Science	
Laser Altimeter (LA)	11 kg
Ice Penetrating Radar (IPR)	10 kg
Radio Science Instrument (JRST+USO)	4 kg

JUICE Key Properties for Science Ops

1. Power generation and spacecraft pointing
    a. Ganymede phase:
        – Baseline is yaw steering
        – Temporarily stable nadir pointing (with power saving operations)
    b. Flybys: any spacecraft orientation

2. Simultaneous operations of remote sensing and *in situ* instruments to be studied

3. Fixed HGA (>3 m)

Mission Profile

Mission Profile – Launch and Interplanetary Transfer

	Prev.Baseline (EJSM/JGO)	**Baseline JUICE**
Launch	March 2020 (June 2022)	**June 2022 (Aug 2023)**
Launch mass in kg	4212 (4681)	**4804**
Interplanetary transfer (Launch to Jupiter arrival) in yrs	5.9 (7.3)	**7.6 (8.0)**
Gravity assist sequence	VEE (EVEE)	**EVEE**
Jupiter arrival	Feb 2026 (Jun 2029)	**Jan 2030 (Aug 2031)**
Total ΔV in m/s	1365 (1685)	**1284 (1315)**
Max. available mass at Jupiter in kg	2680	**3140 (3100)**

Mission Profile – Jupiter Mission Science Phases

1. Europa flybys: 2 flybys immediately following each other; same true anomaly of Europa, outer flyby at ~180° $long_{Europa}$, 400 – 500 km, 36 d

2. Callisto flybys to increase of inclination: reaching Jupiter latitudes up to 30°, 11 flybys (200 d)

3. Ganymede (polar) phases
   a. Elliptic phase starting 10,000x200 km, 30 d
   b. High altitude circular phase 5,000 km, 90 d
   c. Elliptic phase ending 10,000x200 km, 30 d
   d. 500 km circular, 102 d
   e. 200 km circular, 30 d

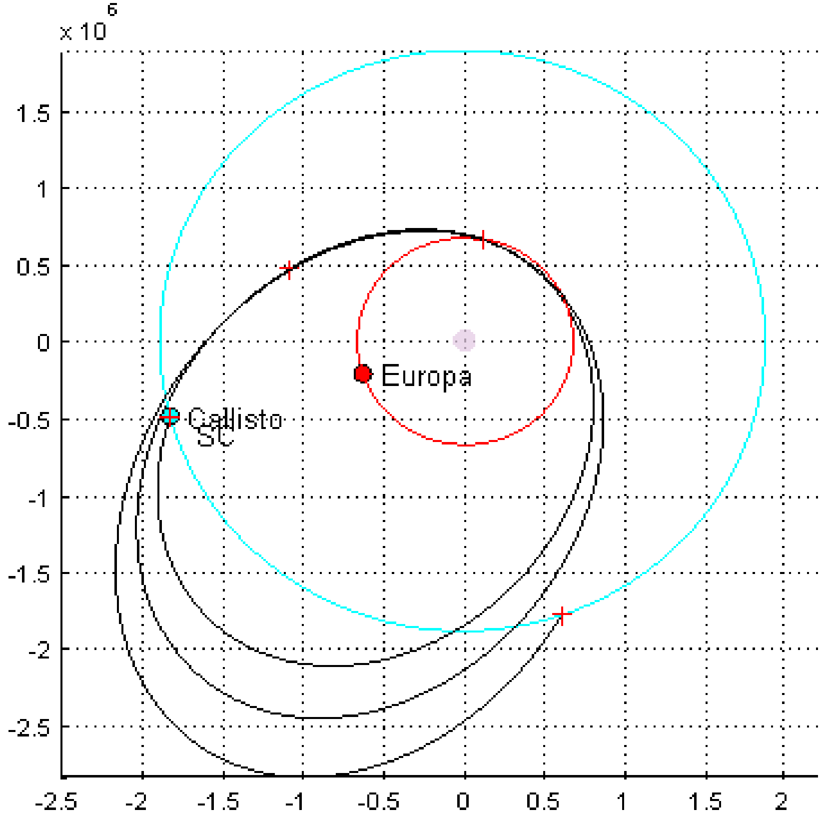
4. Disposal on Ganymede's surface

JUICE/Laplace Mission Timeline

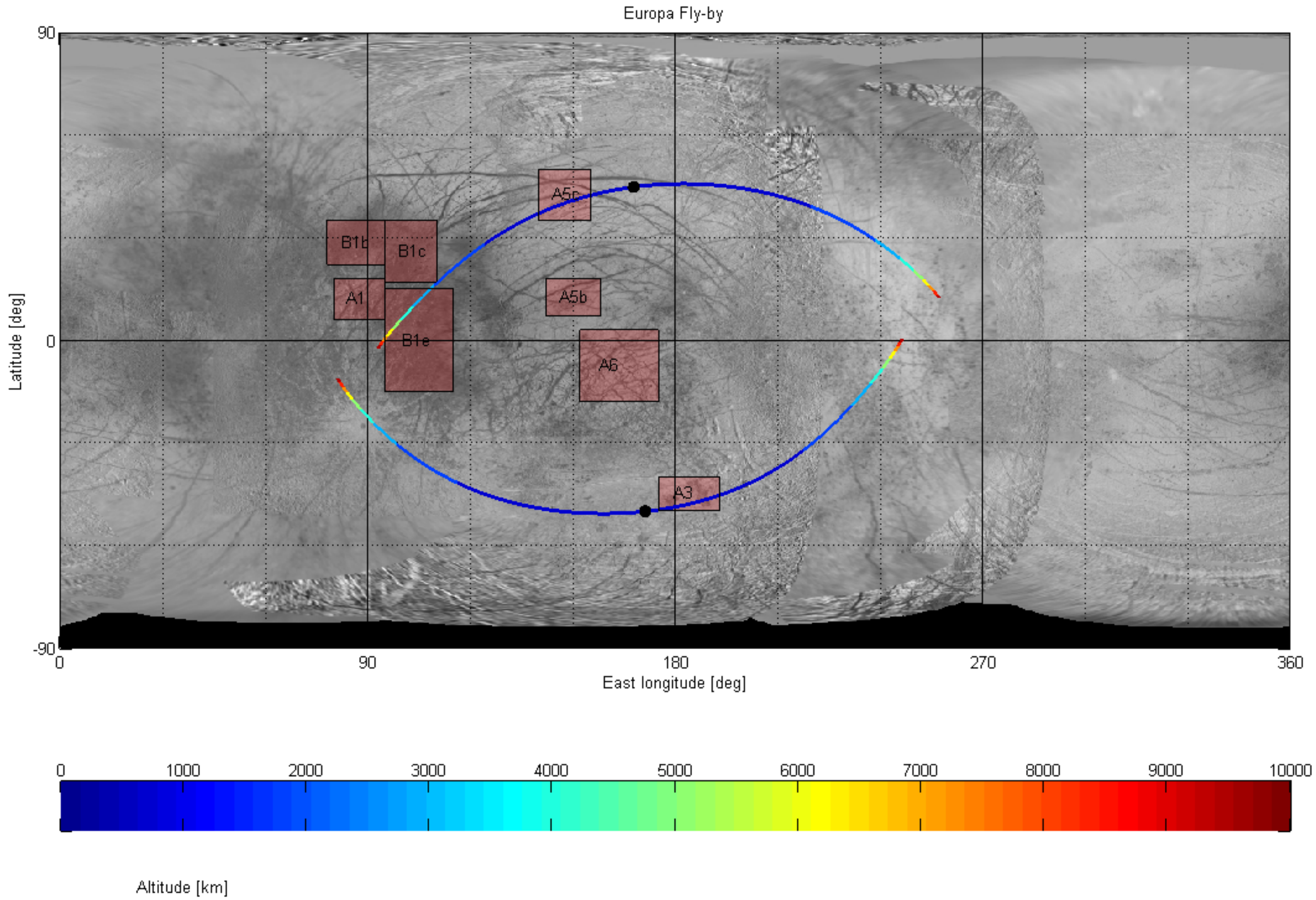
	Baseline	Backup
Launch	Jun 2022	Aug 2023
Interplanetary transfer	7.6 yrs	8.0 yrs
JOI	Jan 2030	Aug 2031
JOI to Callisto	11 months	
Arrival at Callisto	Dec 2030	Jul 2032
Europa Flybys	36 days	
Reduction of V_{inf}	60 days	
Start Callisto High Lat Phase	Mar 2031	Oct 2032
Callisto High Latitude Phase	200 days	
End Callisto High Latitude Phase	Oct 2031	Apr 2033
Callisto to Ganymede + Reduction of V_{inf}	11 months	
GOI	Sep 2032	Mar 2034
Ganymede Elliptical Phase 1	30 days	
Ganymede 5000 km circular Phase	90 days	
Ganymede Elliptical Phase 2	30 days	
Ganymede alt reduction	Feb 2033	Aug 2034
Ganymede 500 km circular Phase	102 days	
Ganymede alt reduction	May 2033	Dec 2034
Ganymede 200 km circular Phase	30 days	
End of mission	Jun 2033	Dec 2034

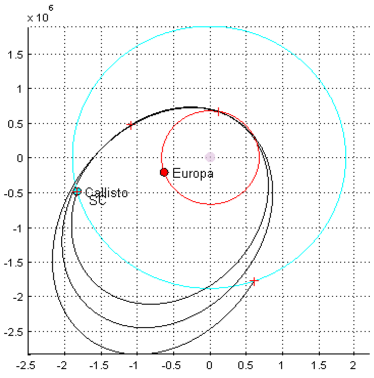
Europa Flyby Scenario

1. 36 day flyby period from leaving Callisto until return to Callisto
2. 2 Europa fly-bys
3. First flyby 9.5 days after leaving Callisto
4. Second flyby 14 days after the first



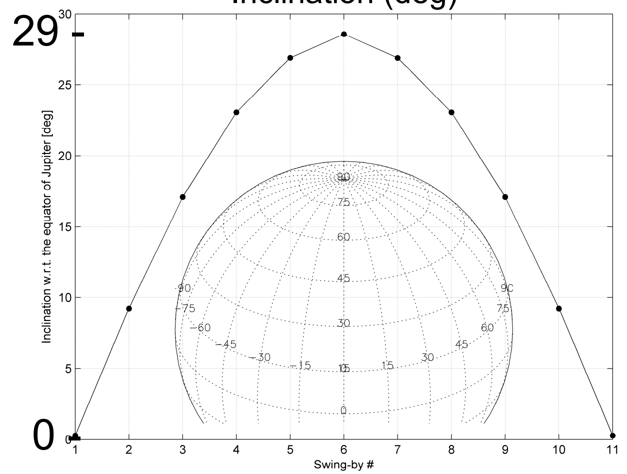
Europa Flybys Ground Tracks



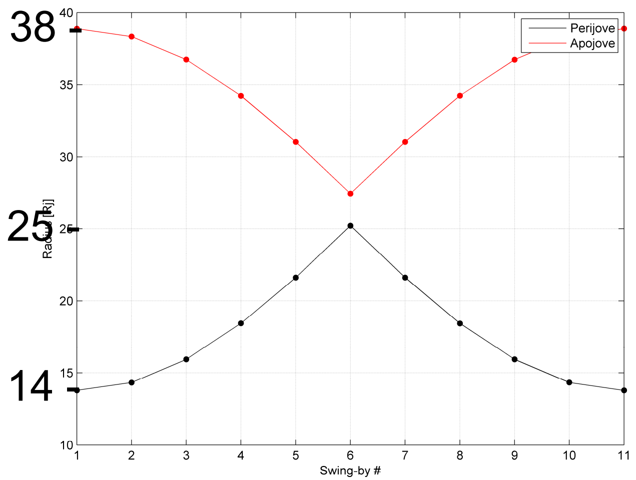


Jupiter High Latitude Phase with Callisto

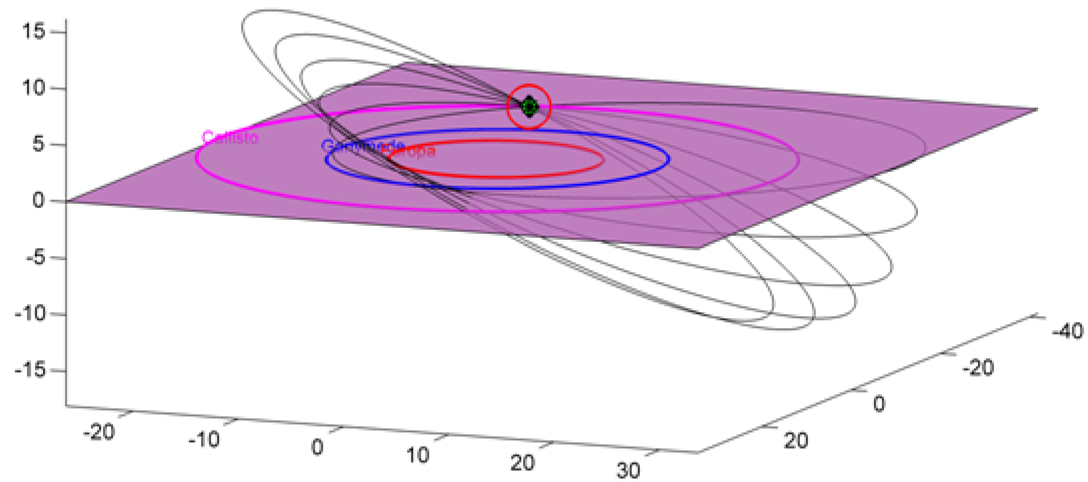
Inclination (deg)



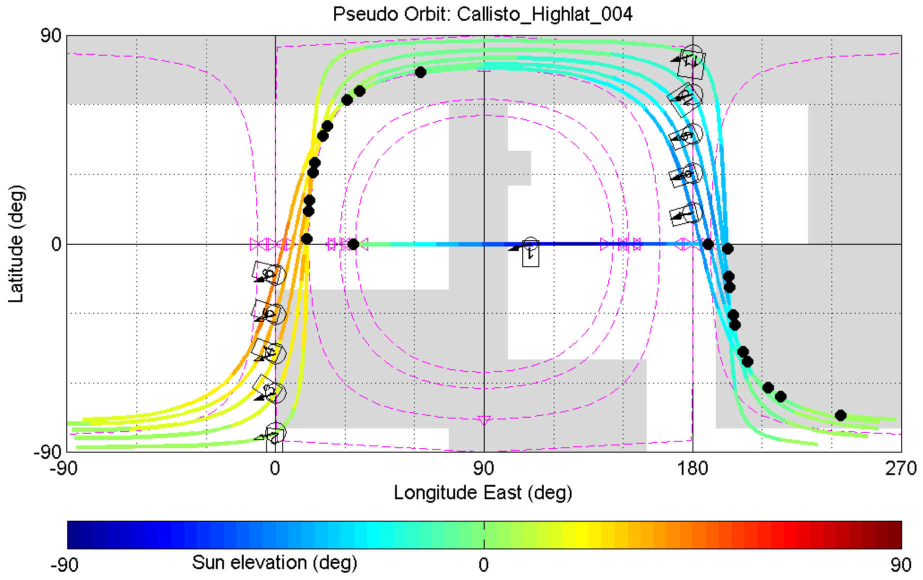
Perijove and Apojove radii (Rj)



- 6 swing-bys are necessary to transfer from equatorial to maximum inclination
- The maximum inclination is ~29 deg
- The time to transfer is 100 days (100x2=200 days for the end-to-end transfer)

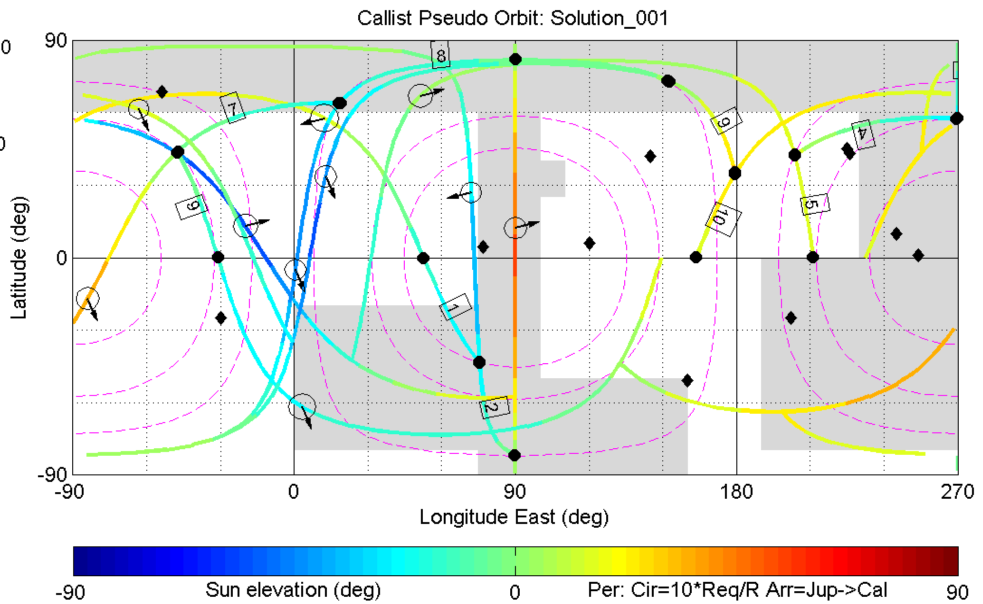


Callisto Coverage



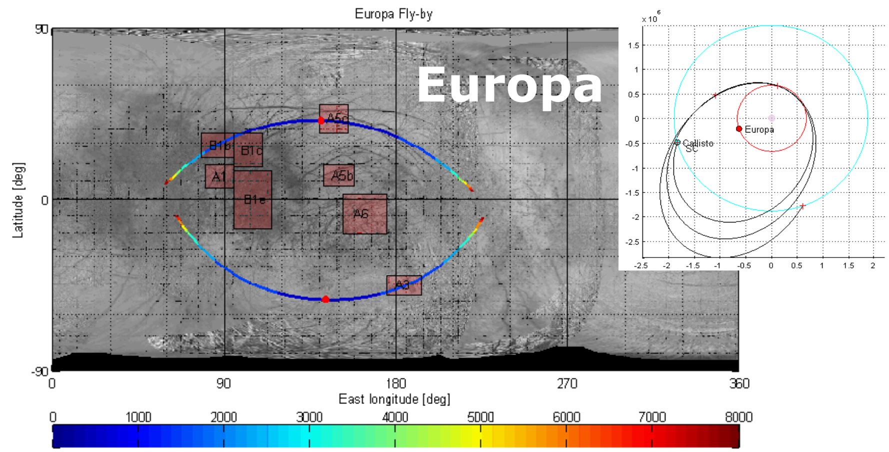
Now: Jupiter High Latitudes

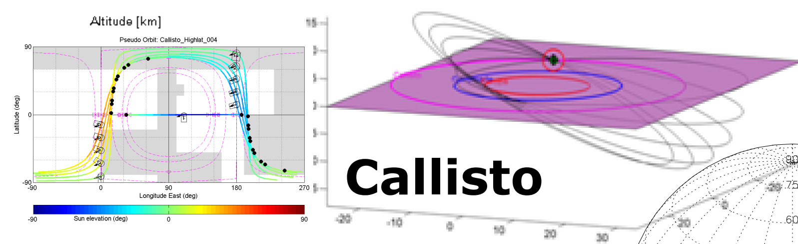
Previous: Pseudo-orbiter

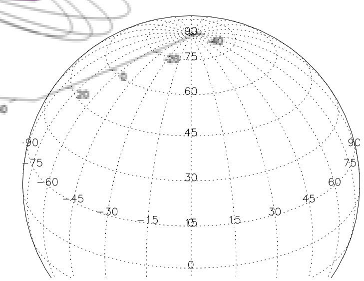


JUICE Mission Profile - Summary

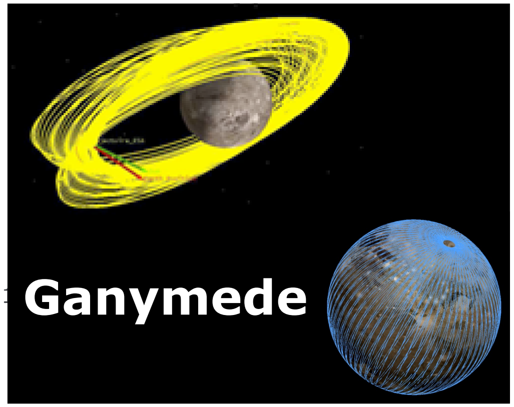
Launch	June 2022 (Aug 2023)
Interplanetary transfer (EVEE)	7.6 (8.0)
Jupiter arrival	Jan 2030 (Aug 2031)
JOI to Callisto	11 mon
2 Europa flybys	36 days
Jupiter high latitude phase	200 days
Callisto to Ganymede	9 mon
Ganymede (polar) 10,000x200 km & 5000 km 500 km circular 200 km circular	 150 days 102 days 30 days







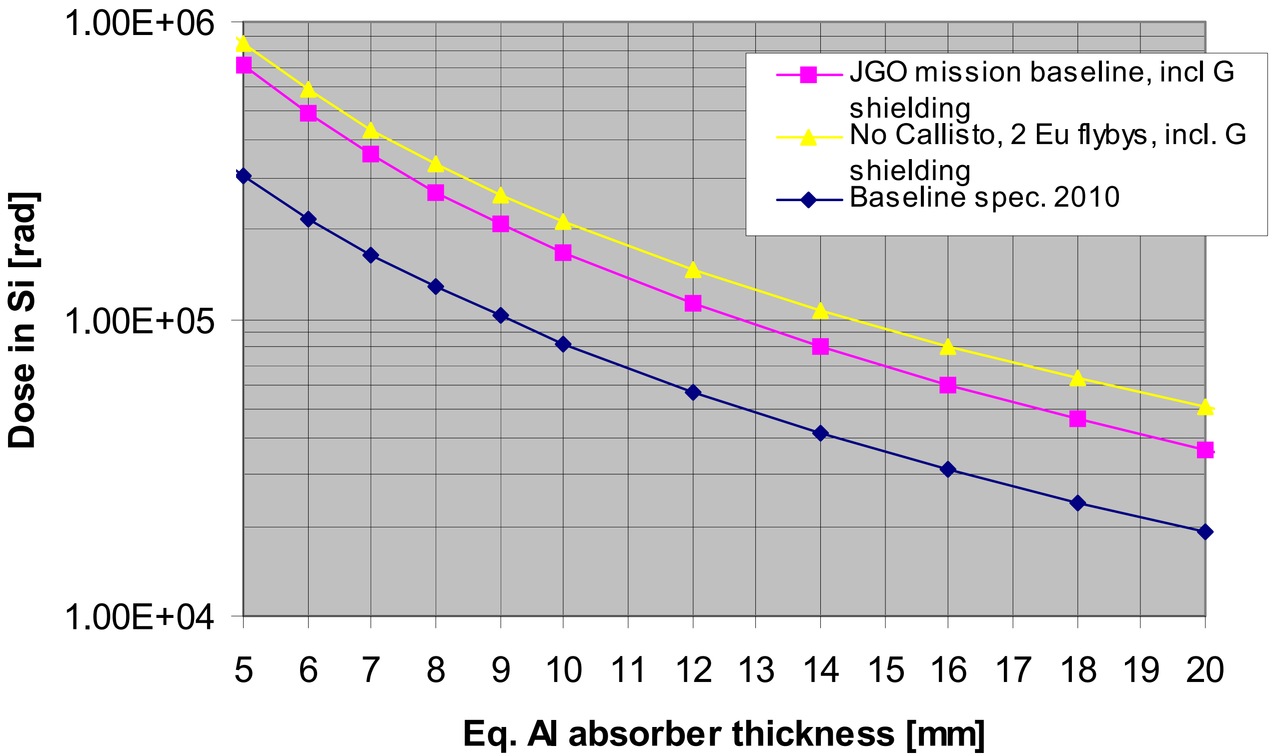
Jupiter Pole



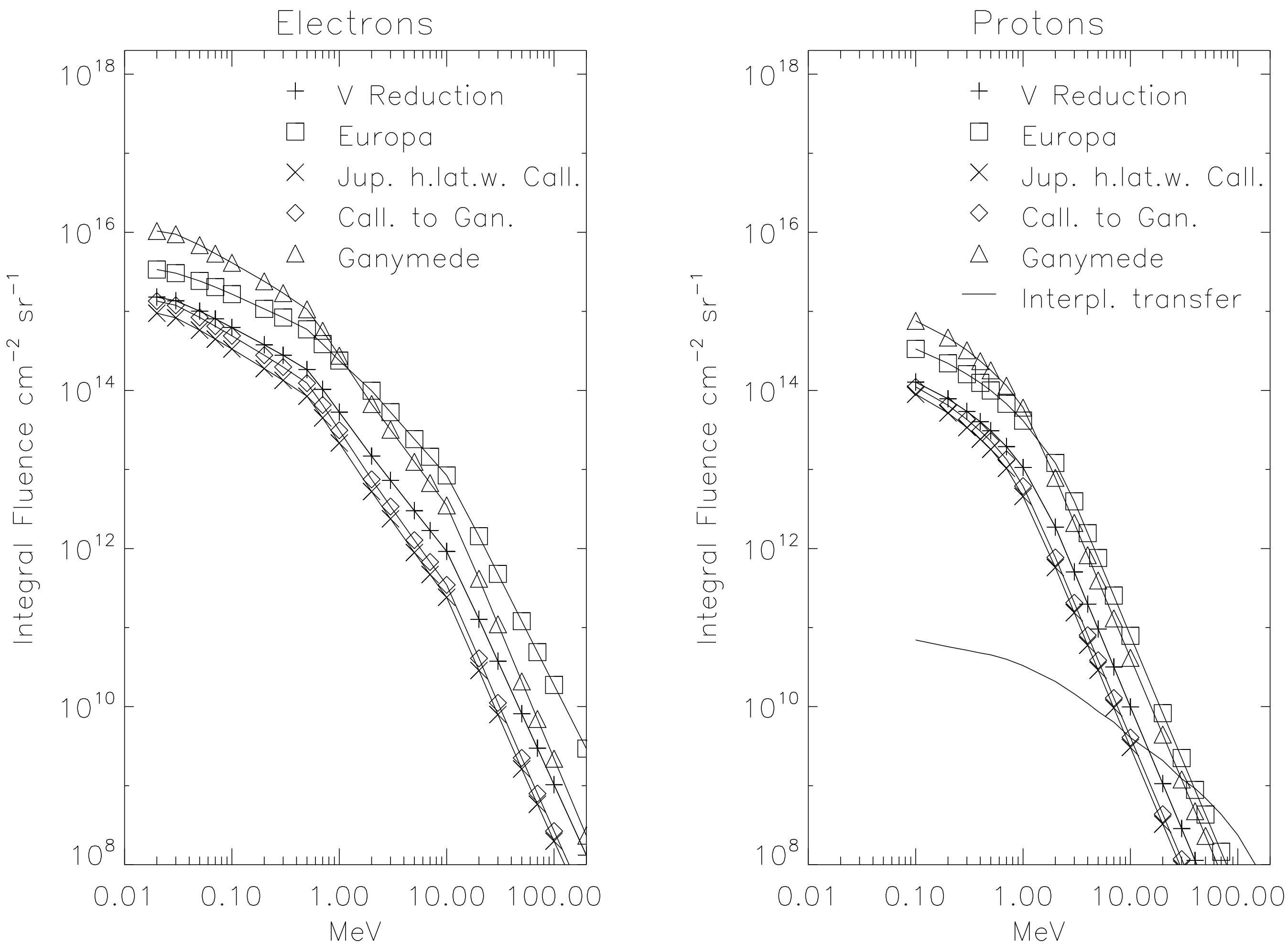
Radiation Environment

Model of the Radiation Environment

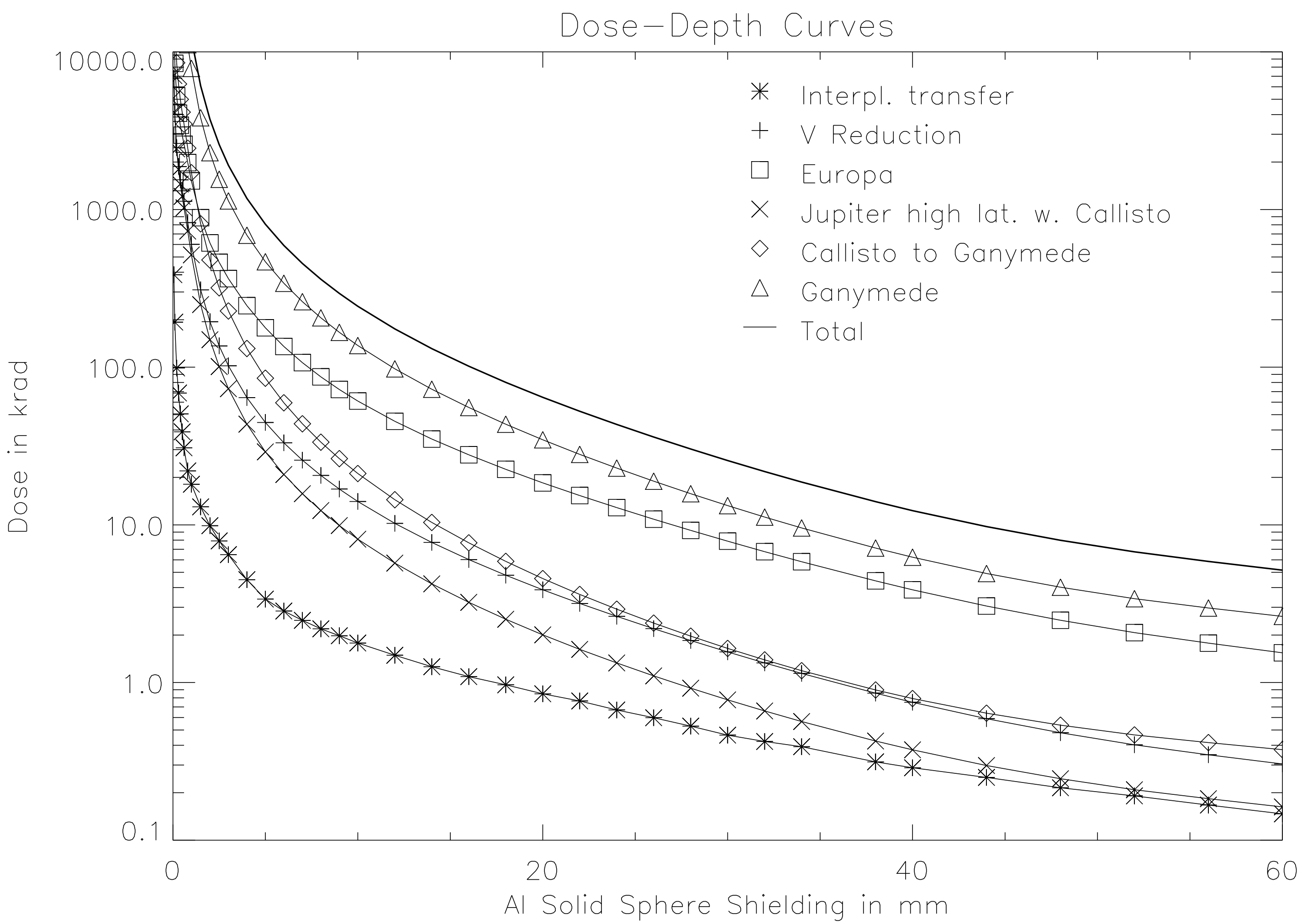
1. Increase of modelled radiation exposure (2x wrt previous baseline)
2. Inclusion of Europa flybys (adds ~20% to total dose)



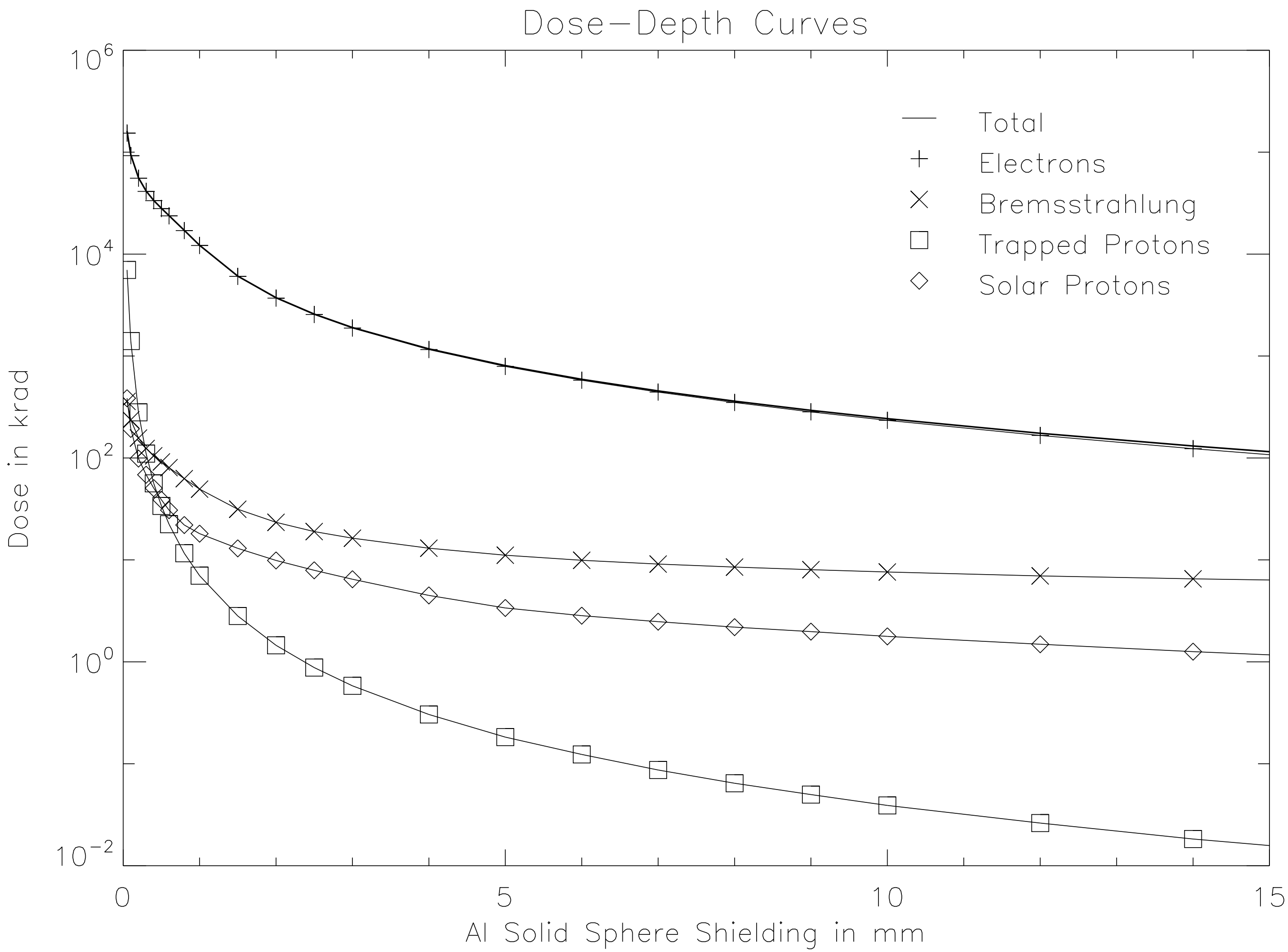
Environment Spectra



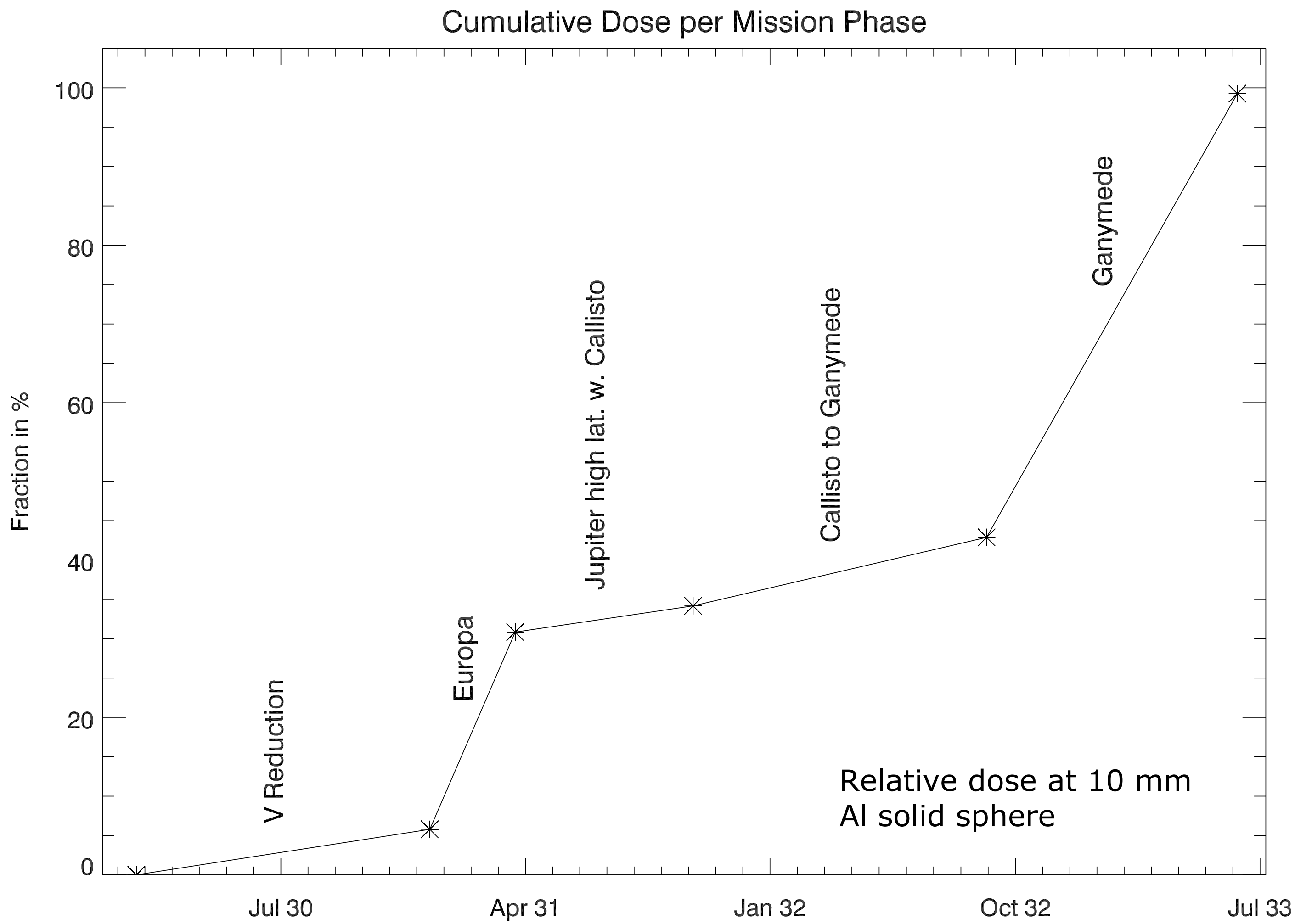
Dose-Depth per Mission Phase



Dose per Particle Species



Cumulative Mission Dose



Model of the Radiation Environment

1. Increase of radiation environment model (2x wrt previous baseline)
2. Inclusion of Europa flybys (adds ~20% to total dose)
3. Radiation mitigation
    a. 3d shielding simulations: reduction of dose by ½ - 1/3 due to geometry from solid sphere to more representative geometry
    b. 40% (conservative) due to shielding by Ganymede during the low altitude phases (≤500 km): 31% of the total exposure at Ganymede
    c. Higher shielding mass than during Assessment Phase
    d. Use of high Z material (Ta) for shielding
    e. Components tolerance required up to 30 krad
4. Radiation environment close to Europa has higher instantaneous flux
    a. Higher background for sensors
    b. No severe increase of Single Event Effects (SEE's)

Planetary Protection

Planetary Protection: Preliminary Assessment

1. Europa flyby requires mission to be in PP Cat III
    a. Requirement: 10^{-4} probability of ocean contamination during mission life and 300 years (in case of failure)

2. Probability of collision with Europa (allocations)
    a. JGO: orbit has too high energy for collision with Europa; very low likelihood – assumption from previous study
    b. Only change with respect to JGO is 2 ballistic Europa flybys
        - Probability of spacecraft failure: $\sim 2\times10^{-3}$ (40 days after 12 years mission)
        - Allocation for likelihood of collision with Europa after failure: $<1\%$

3. Requirement of 10^{-4} probability appears to be feasible, but full analysis to be performed in next phase including
    a. Orbit propagation and collision probability analysis
    b. Failure tree

Approach to Planetary Protection

1. Assume that spacecraft reliability can be demonstrated
2. Active bioburden reductions are assumed as risk (cost impact)

3. Activities in phase A/B1:
    a. Failure tree analysis and likelihoods
    b. Quantification of risks
    c. Consolidation of PP requirements

4. Review at preliminary requirements review

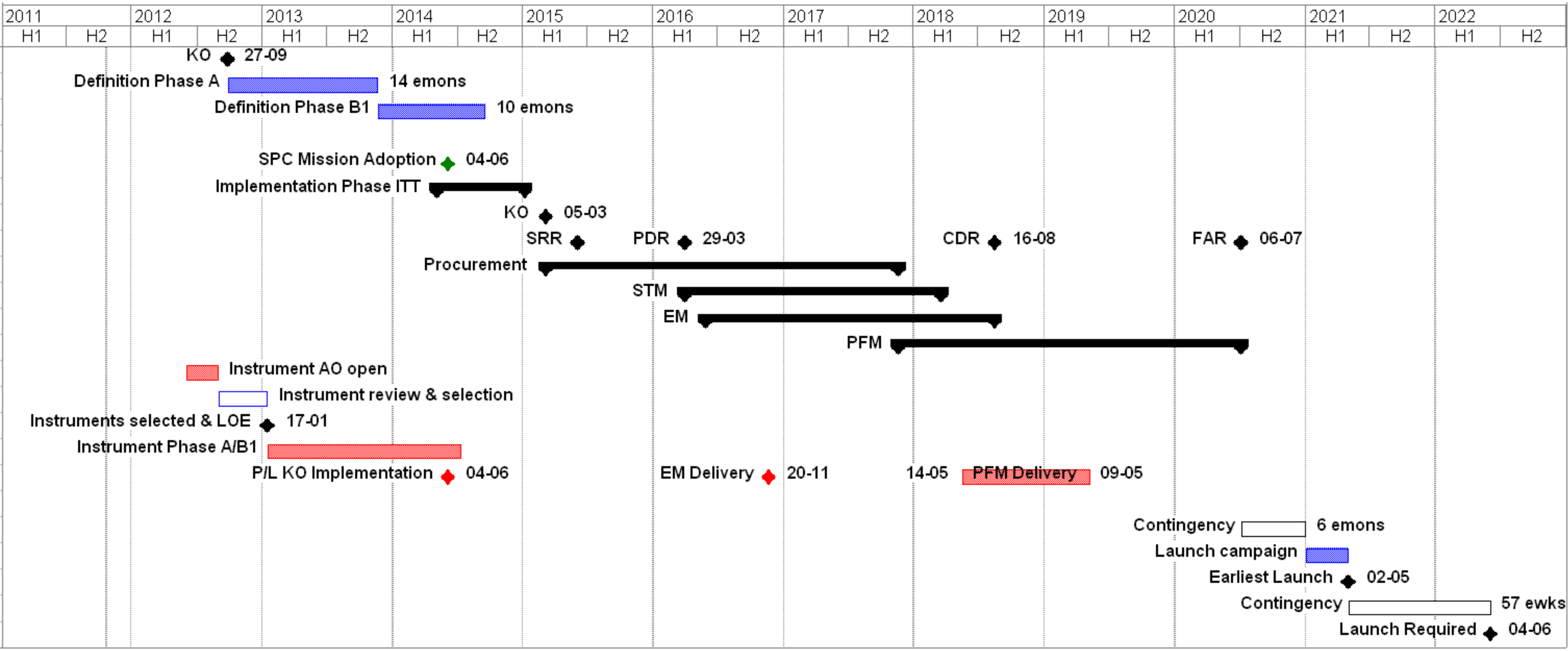
5. Instruments should follow the same approach

Next Steps & Tentative Schedule

Next Steps: Plans for Reviews and Milestones

1. New issue of Yellow Book ready	Dec 2011
2. ESA internal review	Nov/Dec 2011
3. Evaluation of reformulated mission by ESA advisory bodies (SSEWG)	Dec 2011/Jan 2012
4. SPC Down-selection	Feb 2012
5. If down-selection successful –	
a. ITT for industrial Phase A/B1	Q2/2012 (tentative)
b. Issue of instrument AO	Q2/2012 (tentative)

Tentative Implementation Schedule



Summary Spacecraft Updates

1. Configuration and model payload unchanged

2. Increase of radiation exposure balanced by
   a. Moderate increase of shielding mass by ~50 kg
   b. High Z shielding material (Ta as opposed to Al)
   c. Higher component tolerance (up to 30 krad)
   d. Mitigations justified by preliminary transport simulations

3. Minor additional ΔV required for the additional mission options
   a. Higher Jupiter latitude with Callisto gravity assists
   b. Europa flybys

4. Increased dry mass feasible due to
   a. Higher launch capability (+360 kg)
   b. Longer interplanetary transfer (reduction of ΔV)

5. Mission dry mass margin close to 20%
   a. No adverse effect on solar panels

Summary for Instruments

1. Radiation environment
    a. 3d transport simulations very important (Monte Carlo)
    b. Need representative models early

2. Planetary protection
    a. Need estimate for active bioburden reduction as risk

3. Resource optimizations important
    a. Mass criticality