JUMPER: JUpiter MagnetosPheric boundary ExploreR

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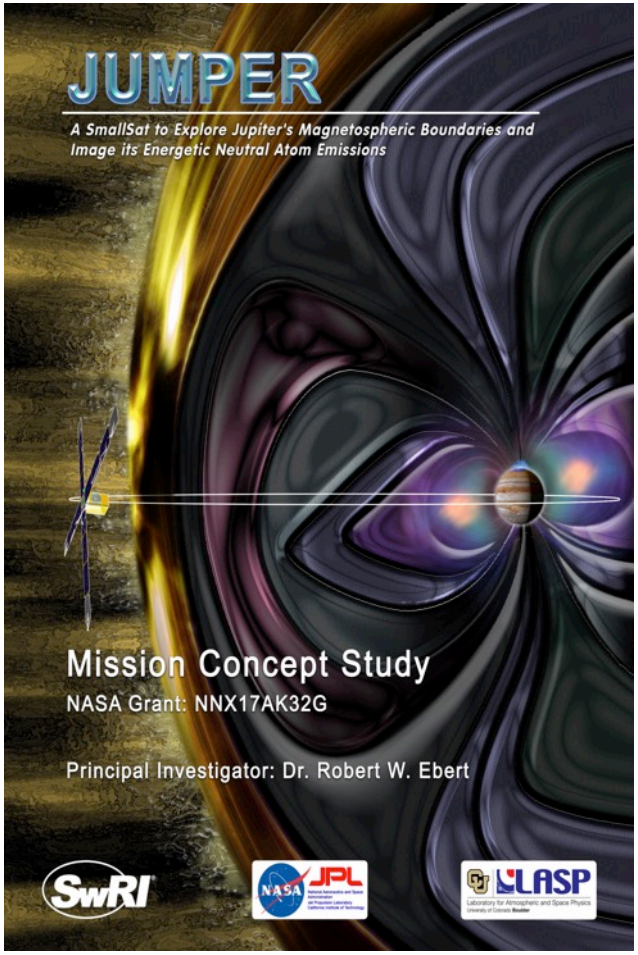
Planetary Science Deep Space SmallSat Studies
Sunday March 18, 2018

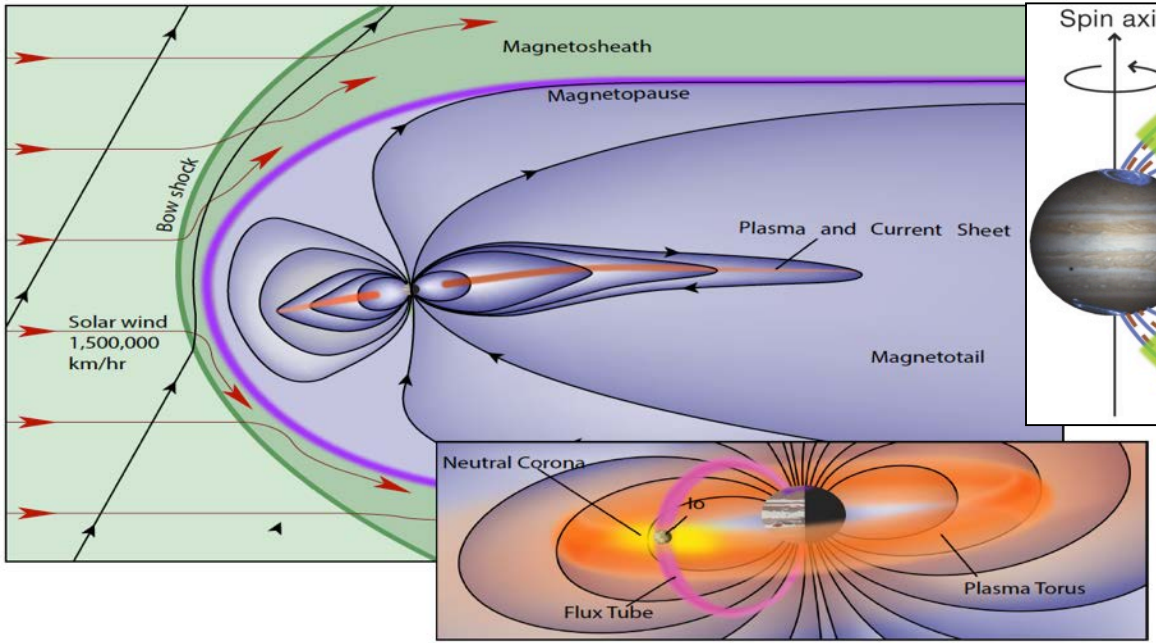
What is JUMPER?

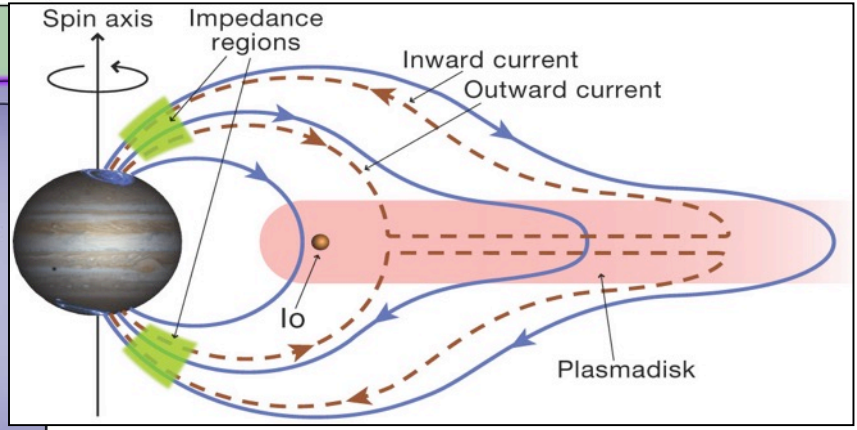
- A Jupiter orbiting SmallSat mission concept.
  - It rides to Jupiter on a primary spacecraft.
- Science focuses on Jupiter's magnetosphere.
- Spacecraft details.
  - ESPA-class.
  - Solar powered.
  - Direct-to-Earth (DTE) communications.
  - Hydrazine propulsion.
- Final report delivered to NASA on 12/29/17.
  - 7 month project.



JUMPER

Jupiter's Magnetosphere





JUMPER focuses on two science topics:

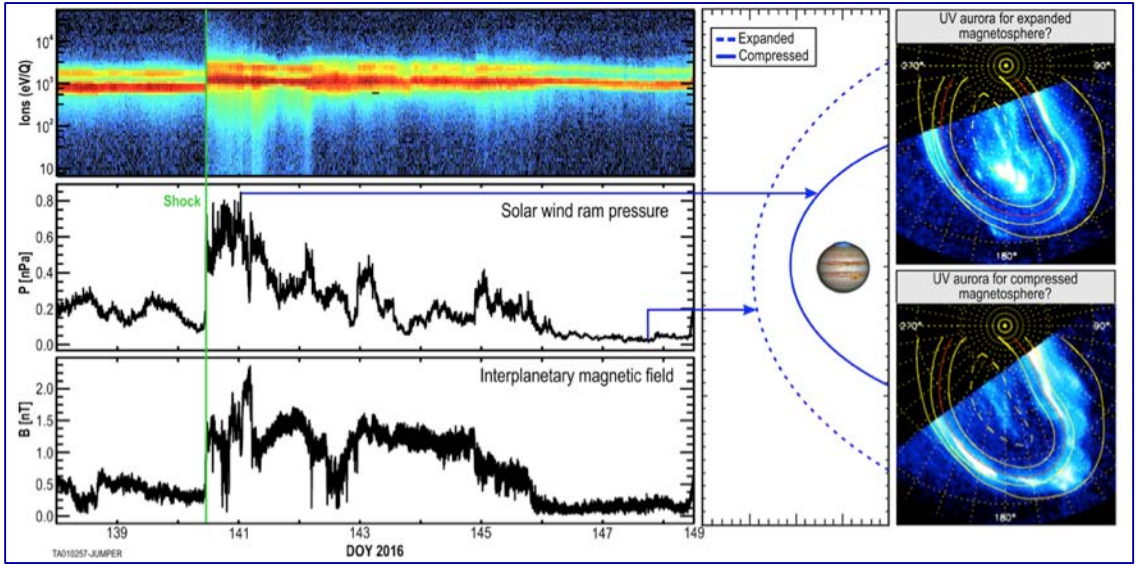
1. The solar wind's impact on Jupiter's magnetosphere.
2. Mass and energy transport through Jupiter's magnetosphere.

Science Question #1

How does the solar wind (SW) influence the configuration and dynamics of Jupiter's magnetosphere?

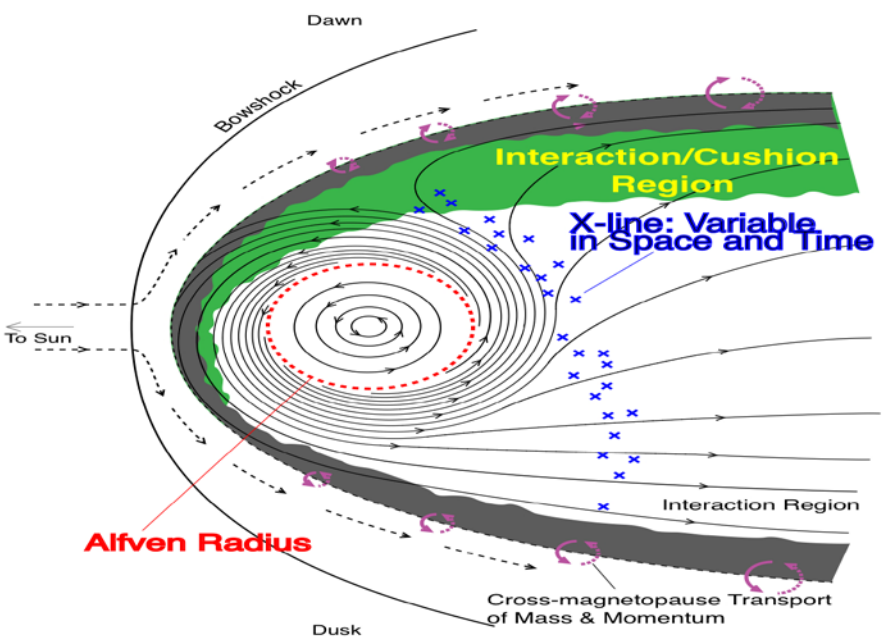
Processes with evidence of SW influence

- **Motion of Jupiter's bow shock and magnetopause.**
- Opening and closing of magnetic flux at the magnetopause.
- Transport of mass & energy into the magnetosphere.
- **Variations in UV aurora brightness and morphology.**
- Radio emission enhancements.
- Current sheet asymmetries in magnetotail.

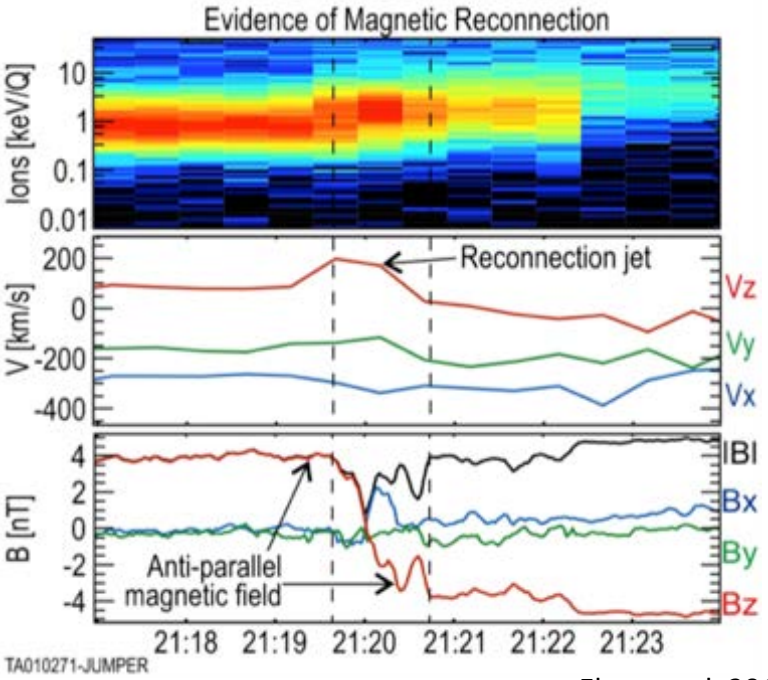


Science Question #2

How does the SW interact with Jupiter's magnetopause?



Delamere & Bagenal 2010



Ebert et al. 2017

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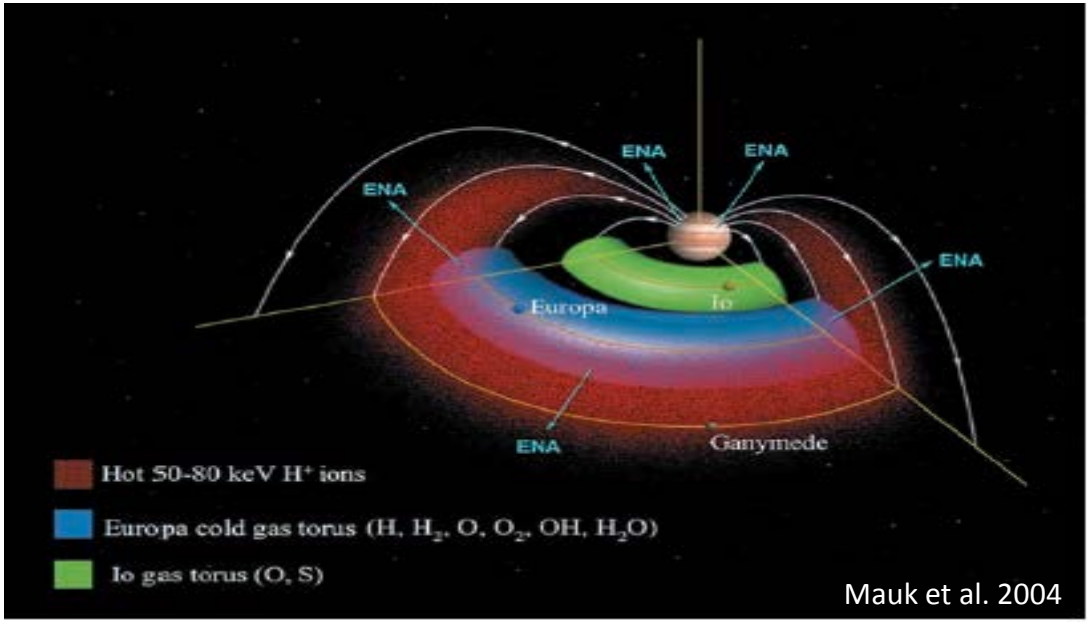
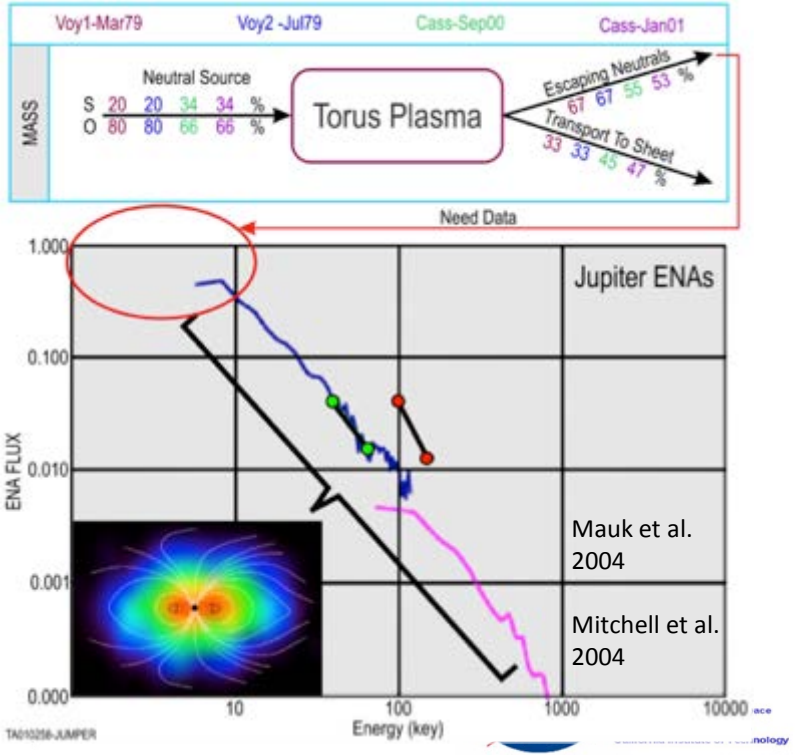
Science Question #3

What are the flux and energy spectra of energetic neutral atoms (ENAs) escaping Jupiter's magnetosphere?

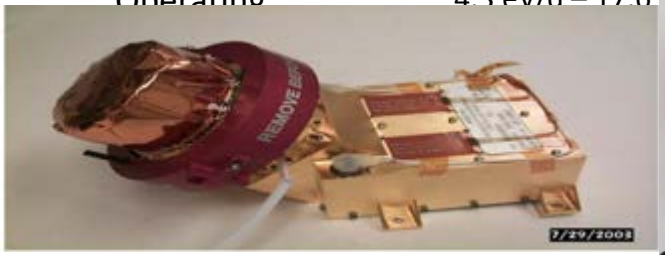


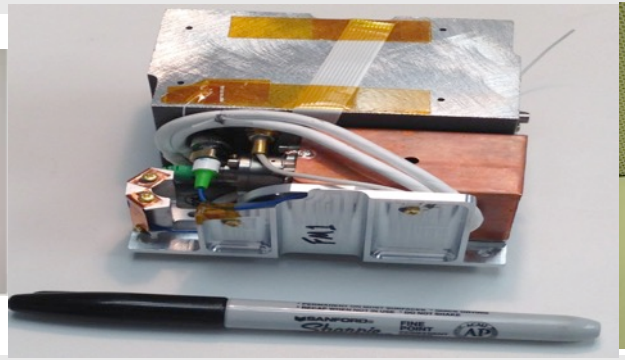
Mauk et al. 2004

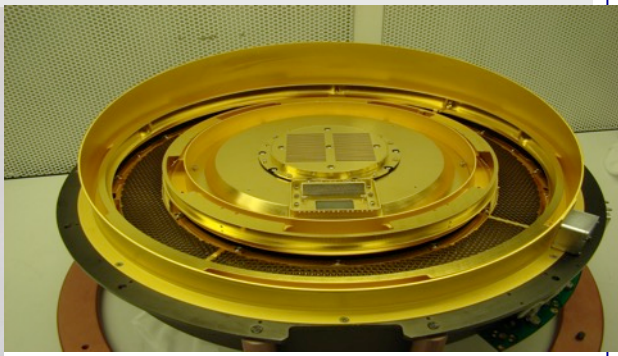


JUMPER Science Payload

Instrument	Ion and Electron Sensor (IES)	Magnetometer (MAG)	Neutral Atom Imager (NAI)
Baseline Design	Electrostatic Analyzer + Detector	Vector Helium Magnetometer	Single Pixel Imager
Operating	4.3 eV/q – 17.6		
Power	1.85 W		
Heritage	Rosetta/IES	INSPIRE, CuSP, Europa/ICEMAG	TWINS, IBEX-Hi, IMAGE/ MENA, Cassini/INCA







JUMPER targets high heritage science instruments.

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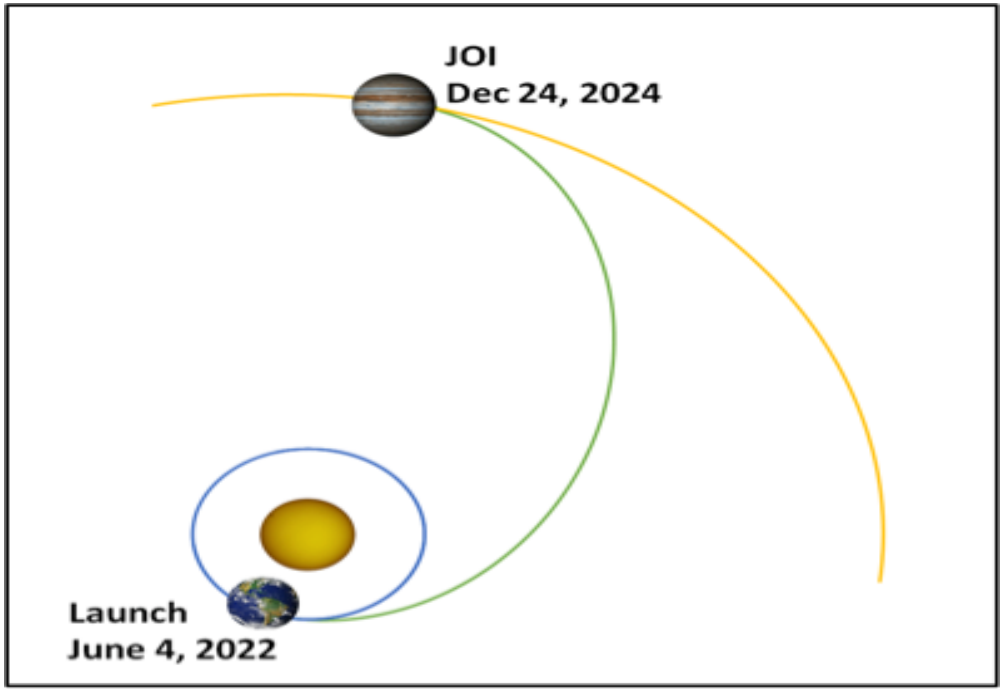
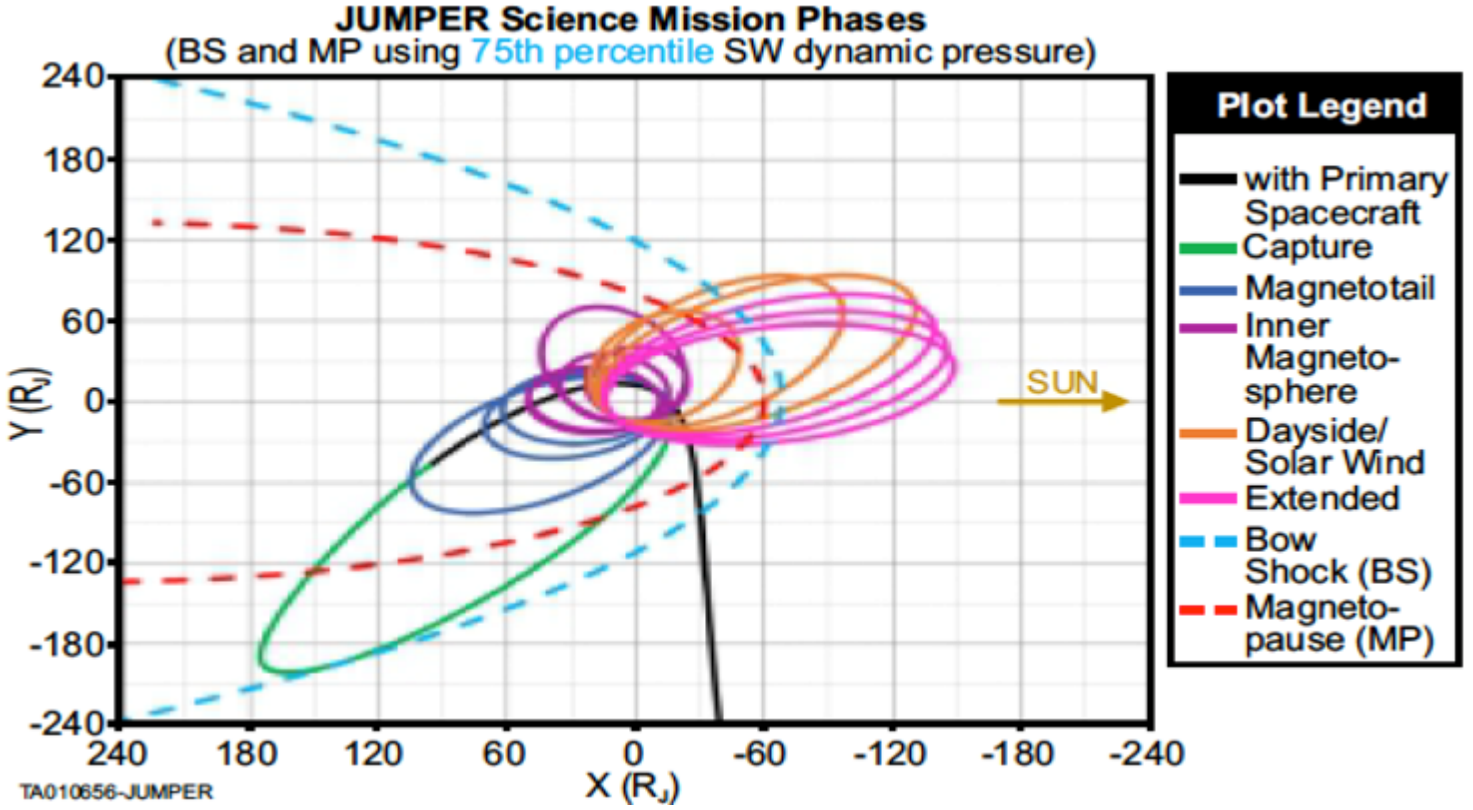
Mission Design

JUMPER Interplanetary Cruise



- JUMPER launches with primary vehicle.
- JUMPER's interplanetary cruise is expected to last 2.5 years.
  - Assuming ride w/ primary vehicle + SLS Launch)
- Primary spacecraft + JUMPER arrive at Jupiter.
- JUMPER rides with primary spacecraft through Jupiter orbit insertion (JOI).

Mission Design



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JUMPER Mission Design

Table A: Tour trajectory details by orbit

Orbit Number	Duration Days	Name	D
0	85.0	-	1/7/
1	136.7	AJ1	4/1/
2	53.5	AJ2	8/16
3	32.1	AJ3	10/9
4	24.9	AJ4	11/1(
5	21.2	AJ5	12/5
6	18.8	AJ6	12/2(
7	17.7	AJ7	1/14
8	26.4	AJ8	2/1/
9	26.5	AJ9	2/27
10	17.5	AJ10	3/25
11	26.5	AJ11	4/12
12	53.4	AJ12	5/9/
13	82.3	AJ13	7/1/
14	46.4	AJ14	9/21
14*	93.1*	AJ14	9/21
15*	93.1	AJ15	12/23
16*	93.0	AJ16	3/26
17*	46.8	AJ17	6/27

TA010659-JUMPER

Table 19: Satellite Flybys

Flyby	Orbit#	Date	C/A (km)
G1	1	07/12/25	100
G2	2	09/21/25	461
G3	3	10/27/25	268
G4	4	11/25/25	2153
G5	5	12/16/25	475
C1	6	01/03/26	262
G6	6	01/06/26	797
G7	8	02/09/26	188
G8	9	03/17/26	112
G9	11	04/20/26	133
G10	12	05/26/26	372
G11	13	08/05/26	6510
G12*	14	11/07/26	0*/50591
G13	15	02/08/27	4780
G14	16	05/12/27	2289
G15*	17	08/13/27	0*

* indicates flybys with potential end of mission impacts.

Flyby	Science Phase
	Separation & Capture
G1	Magnetotail
G2	
G3	
G4	Inner Magnetosphere
G5	
C1 & G6	
G7	
G8	
G9	Dayside / Solar Wind
G10	
G11	
G12^	^End of nominal mission
G12*	Extended*
G13	
G14	
G15	

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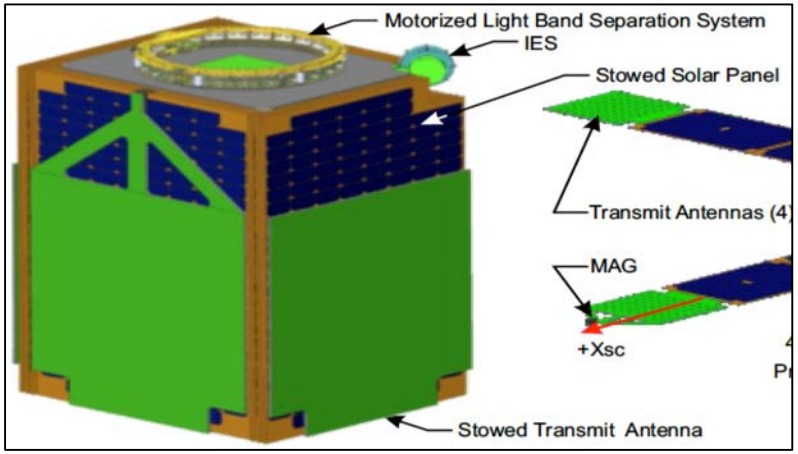
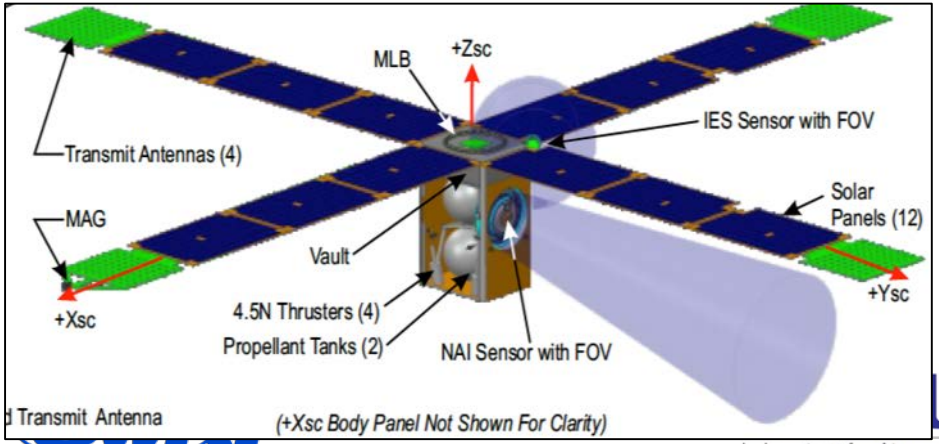
Spacecraft





Key Performance Characteristics

Spacecraft Configuration	3-axis stable, sun pointing, ESPA class
Mass (Dry/Wet)	126 kg/149 kg (CBE)
Solar Panels	4 x tripled deployed, 1994 cells at 29.5% efficiency total area = 5.34 m^2
Raw Power (solar)	64 W Beginning Of Life (BOL) 48 W End Of Life (EOL)
Spacecraft Power (Science Mode)	42.5 W (BOL margin=34%; EOL margin=11%)
Communications	2 kbps X-band Direct-to-Earth with > 3 dB link margin (DSN 34m) 8 kbps X-band Direct-to-Earth with > 5 dB link margin (DSN 70m)
Propulsion	22 kg Hydrazine propellant 336.8 m/s of delta-V (21% margin)
Radiation in Vault	10 kRad TID (RDM=2)
Mission Duration	Prime: 1.84 years; Extended: up to 2.63 years

ESPA-Class Limits

Mass: 180 kg;

Volume: 61 cm x 71.1 cm x 96.5 cm

Commun. & Data System

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Table 16: Data Volume Production & Availability for JUMPER Prime & Extended Mission (3 Scenarios)			
	Only 70 m Ant.	Half 70 m, half 34 m Ant.*	Only 34 m Ant.
S/C Eng Production (Mb)	6,348	4,793	3,755
MAG Production (Mb)	5,797	4,980	662
NAI Production (Mb)	835	700	348
IES Production (Mb)	13,779	8,099	4,240
Total Production (Mb)	26,759	18,571	9,005
Total Available (Mb)	40,781	25,488	10,195
Total Margin	34%	27%	12%
*Default case for this study			

Antenna

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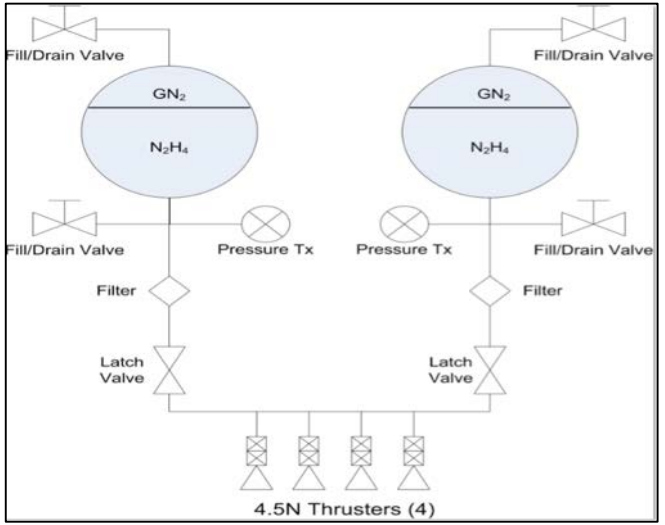
Connectors

Antennas

Hydrazine Propulsion System

- Orbit adjustments are made using a a monopropellant (hydrazine) blowdown thruster system (Moog, inc).
- Total propellant mass is 22 kg.
- 336 m/s of ΔV for the mission.

Delta-V	Allocated	Number	Value
Deterministic [1]	199.8 m/s	1	199.8 m/s
Statistical (flyby corrections)	4 m/s	14	56 m/s
Deterministic [2]	12 m/s	1	12 m/s
Total Required	-	-	267.8 m/s
Total Available	336.8 m/s	[22 kg]	336.8 m/s
DV Margin	-	-	69 m/s
% Margin	-	-	20%



JUMPER hydrazine propulsion system (from Moog, Inc.)

Electrical Power System

The EPS is build around a battery backed main 28V bus and consists of:

Solar Arrays

- 12 (4 x triple deployed solar panels).
- 1944 cells at 29.5% efficiency

A peak-power tracker (PPT)

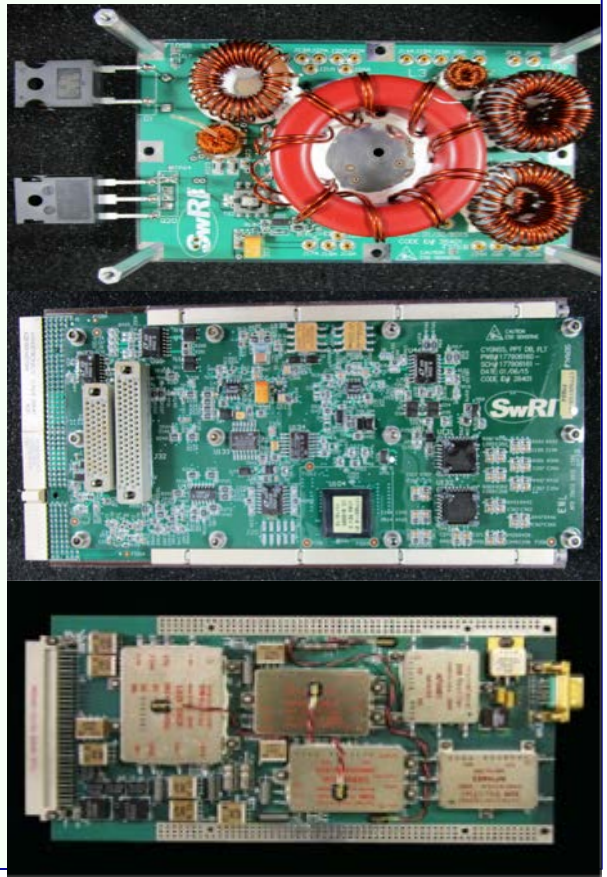
- 94% efficiency; supplies 60 W BOL (45 W EOL) to main 28V bus.

Low-voltage power supply (LVPS)

- Regulates low voltages for use by the SATYR single board computer & PPT.

Batteries

- 640 Whr. of primary and secondary battery capacity.



Flight Avionics Subsystems

SATYR Single Board Computer (SBC)

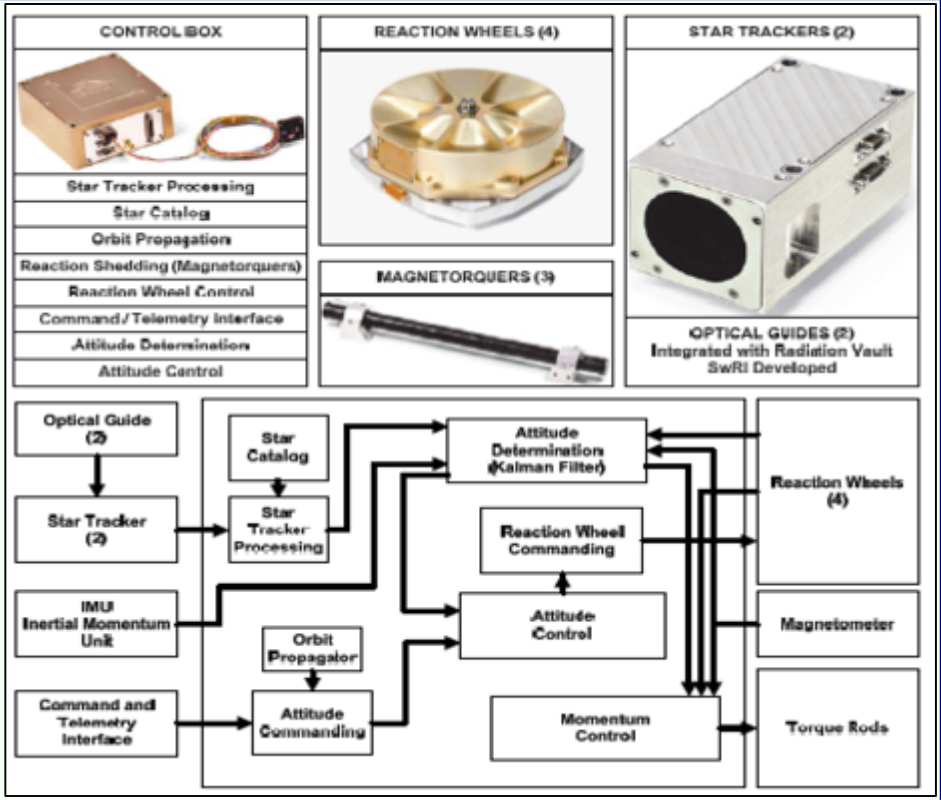
- Performs all on board processing.
- 4 GB of flash memory

Flight Software (FSW)

- Re-use of CYGNSS and CuSP FSW wherever possible.

Attitude Determination and Control System

- Uses COTS components.
- Star trackers are used for pointing.
- Magnetorquers to de-saturate reaction wheels.



Primary Spacecraft Accommodation

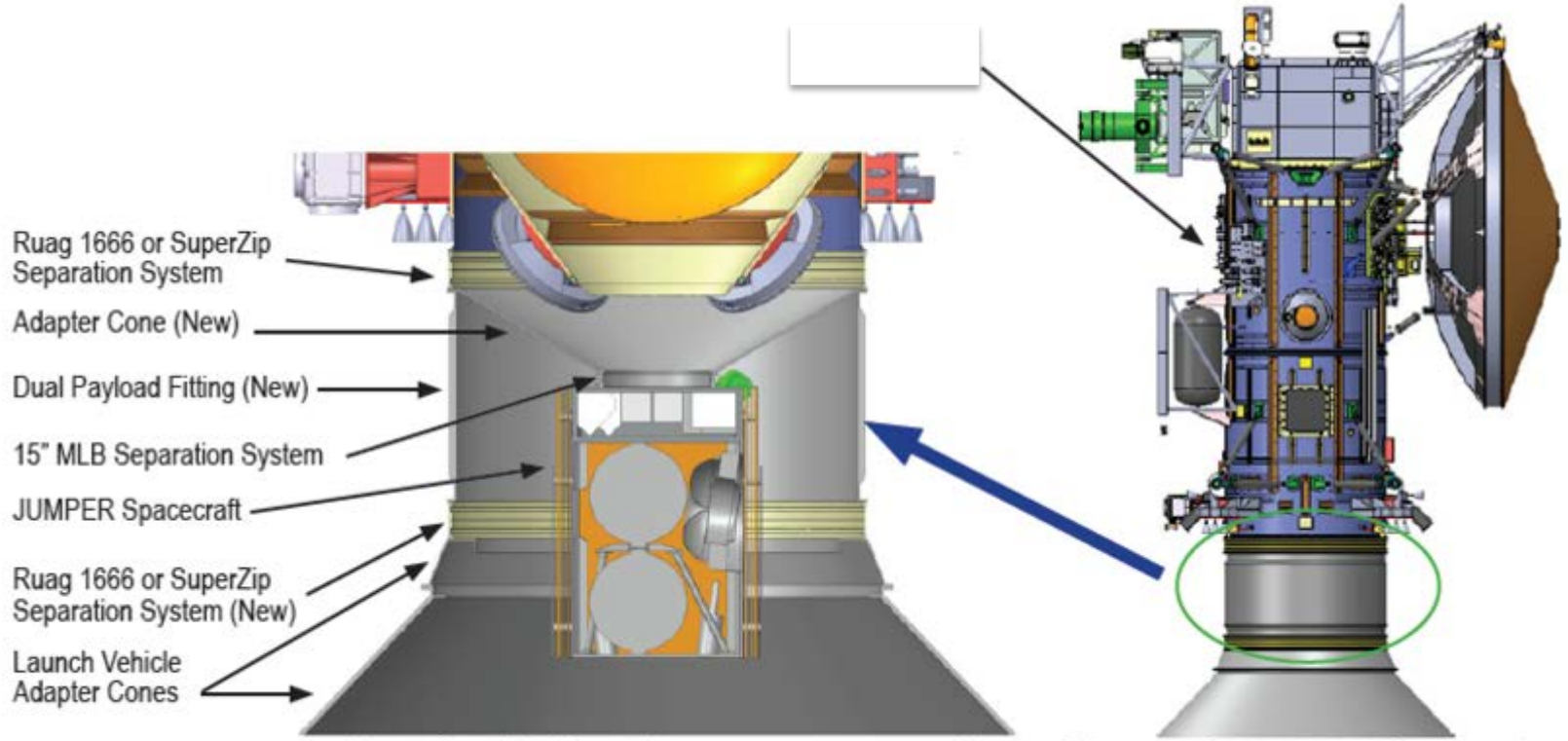
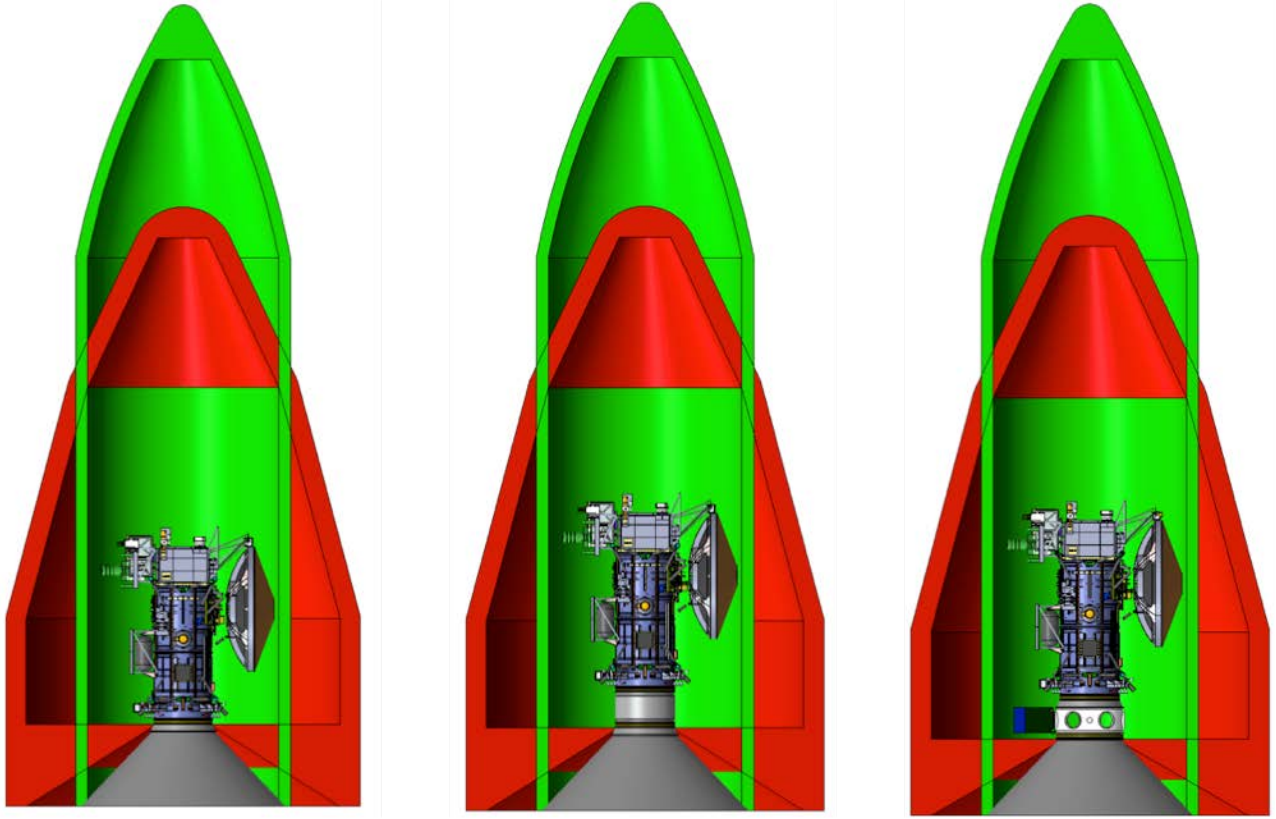
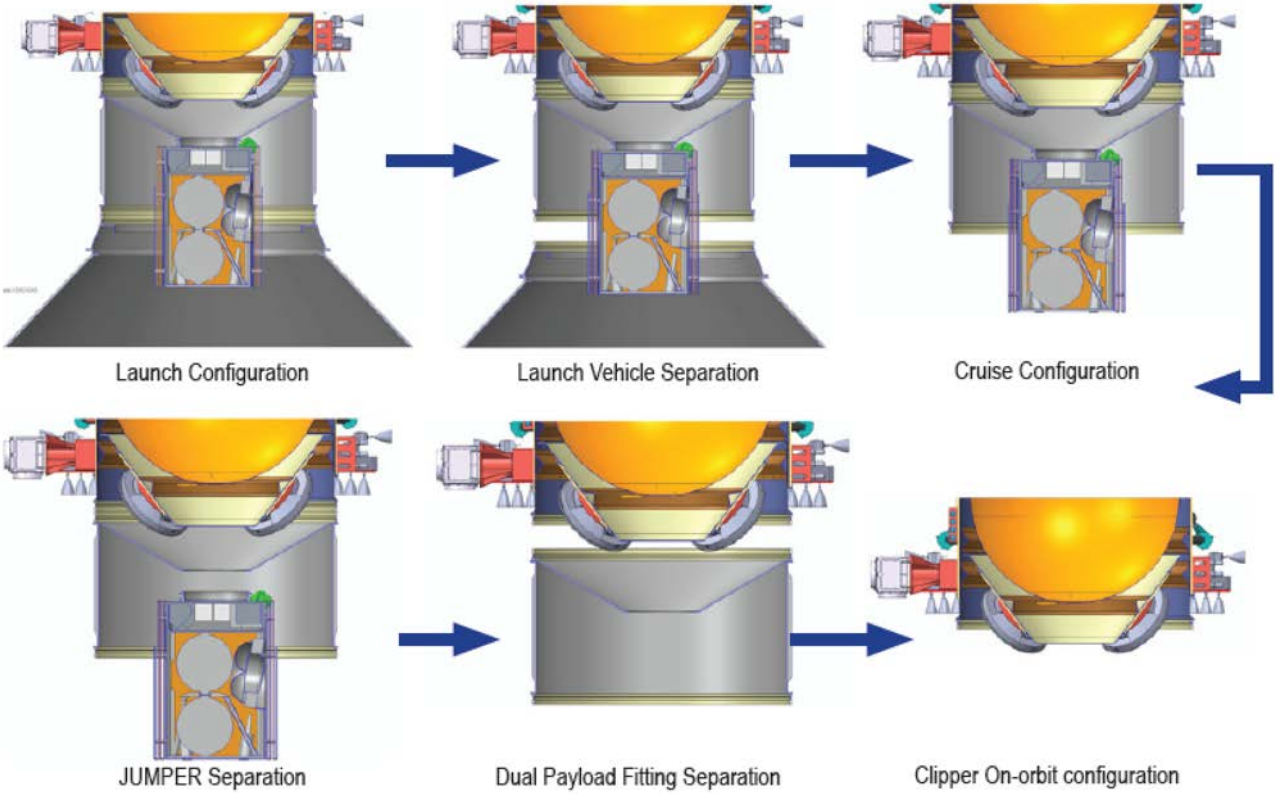


Figure 27: JUMPER launch vehicle and primary spacecraft interface configuration (baseline).

Launch Vehicle Interface



Separation Profile



Summary

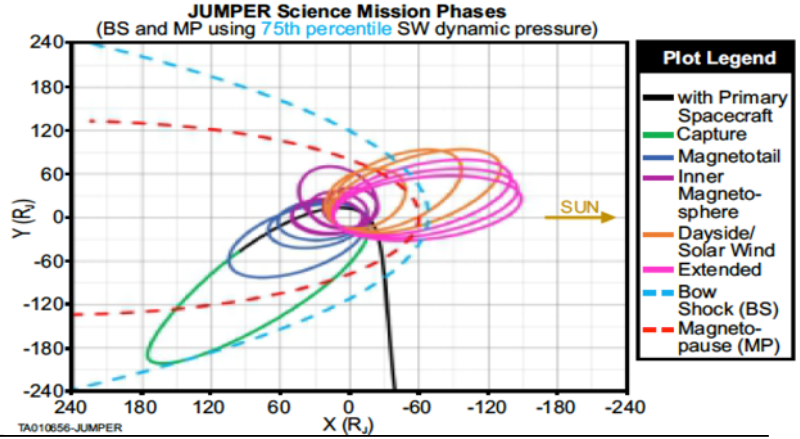
- JUMPER is a Jupiter orbiting SmallSat mission concept to study (i) the solar wind's influence on and (ii) the contribution from ENAs to mass loss from Jupiter's magnetosphere.
- It rides to Jupiter with a primary spacecraft and uses a series of Ganymede and Callisto flybys to achieve its desired orbit.
- It has undergone a mission concept study through NASA's PSDS3 program.
  - Mission details can be found in 2018 IEEE Aerospace Conference publication.
- This mission concept is applicable to other planetary systems.

Mission Summary

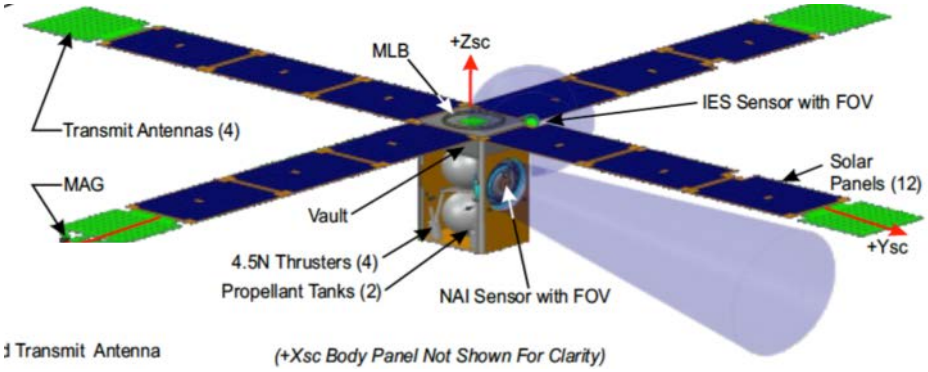
Science Questions

1. How does the solar wind (SW) influence the configuration and dynamics of Jupiter's magnetosphere?
1. How does the SW interact with Jupiter's magnetopause?
1. What are the flux and energy spectra of energetic neutral atoms escaping from Jupiter's magnetosphere?

Mission Design



Spacecraft



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