The 7th Mission Idea Contest
For Deep Space Science and Exploration

PARS: PRECURSOR ASTEROID REMOTE SURVEY

"Pars" means leopard in Turkish and Anatolian leopard is one of the native animals of Anatolia, Turkey.

UNISEC GLOBAL
University Space Engineering Consortium

PARS TEAM

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OUTLINE

1. *Introduction*
2. *Mission Objectives*
3. *Concept of Operations*
4. *Scientific Observations & Outcomes*
5. *Key Performance Parameters*
6. *Spacecraft Design & Project Timeline*

MOTIVATIONS

Preliminary research about asteroid Apophis which is a suitable target for a low-cost technology demonstration

First time detection of seismic effects of Earth flyby from orbit which might lead to a fundamental discovery with a low-cost micro-satellite

The first time in space, use of Laser Doppler Vibrometer

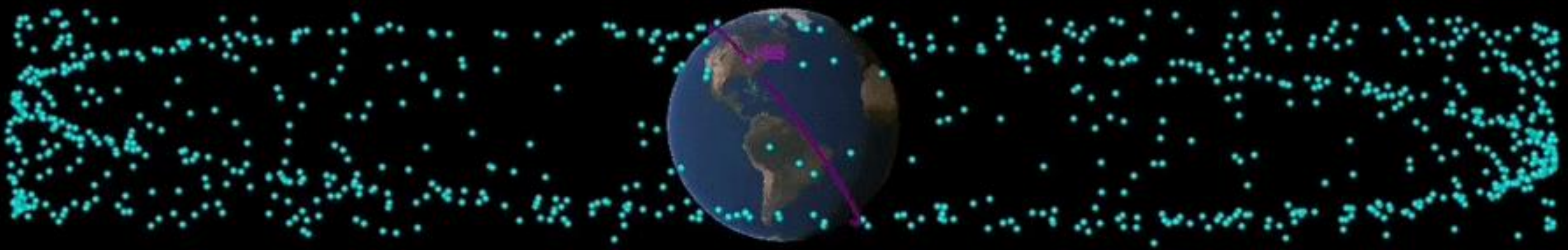
Contribution to the future space economy and asteroid deflection missions through enabling low-cost asteroid exploration

Raising awareness of space science and technology in Turkey

2029 Apr 13, 19:01:46 UTC
1,000x time

WHY APOPHIS?

Close approach on April 13, 2029



- Near Earth Asteroid (NEO)
- Small shape and size
- Seismic activity and tidal effect
- No enough information about morphology

Easy to reach with a low-cost mission
Expected to be affected by Earth flyby
Unique oppurtunity to test LDV / the first orbital seismometry concept
Reference images and data for the future landers to be utilized for a potential deflection mission

MISSION OBJECTIVES

Scientific

1. Apophis Shape & Surface Determination
2. Understanding the Tidal Force Effects

Technology Demonstration

Fly-By Vibration Measurement with a single LDV

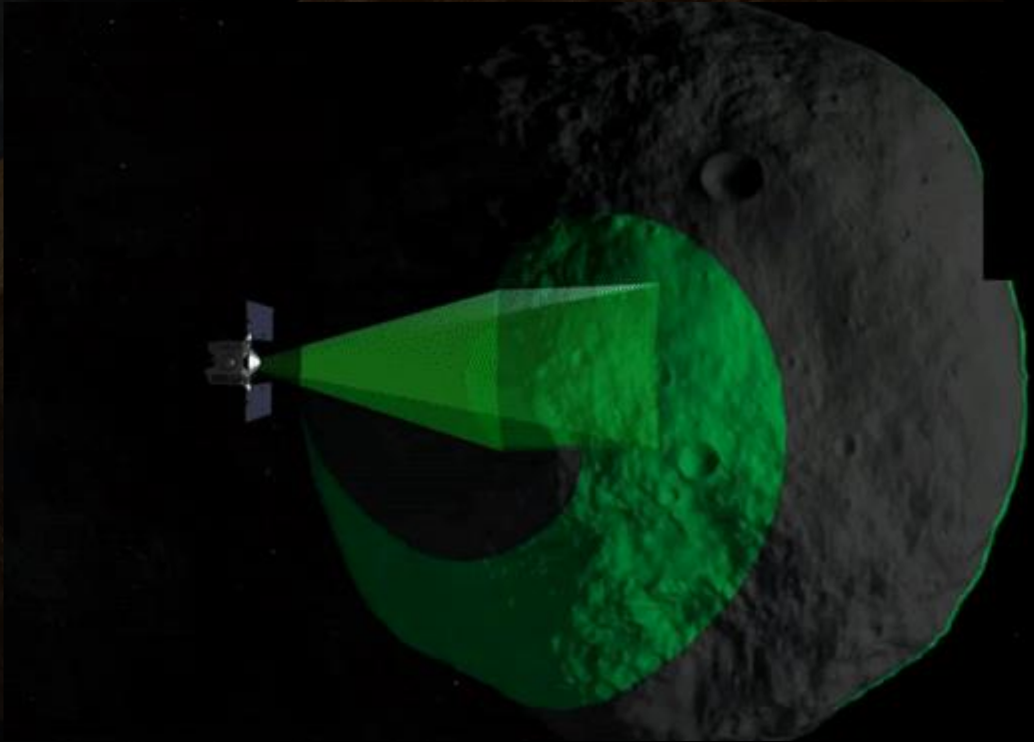
Social

Attracting Interest on Space Studies

Scientific Objectives

Apophis Shape & Surface Determination

- *Requirement:* Characterize Apophis' shape and surface topography.
- *Purpose:* To improve the surface and shape information of the Apophis via 2U LIDAR concept.
- *Techniques:* Utilizing LIDAR measurements and high-resolution camera images.

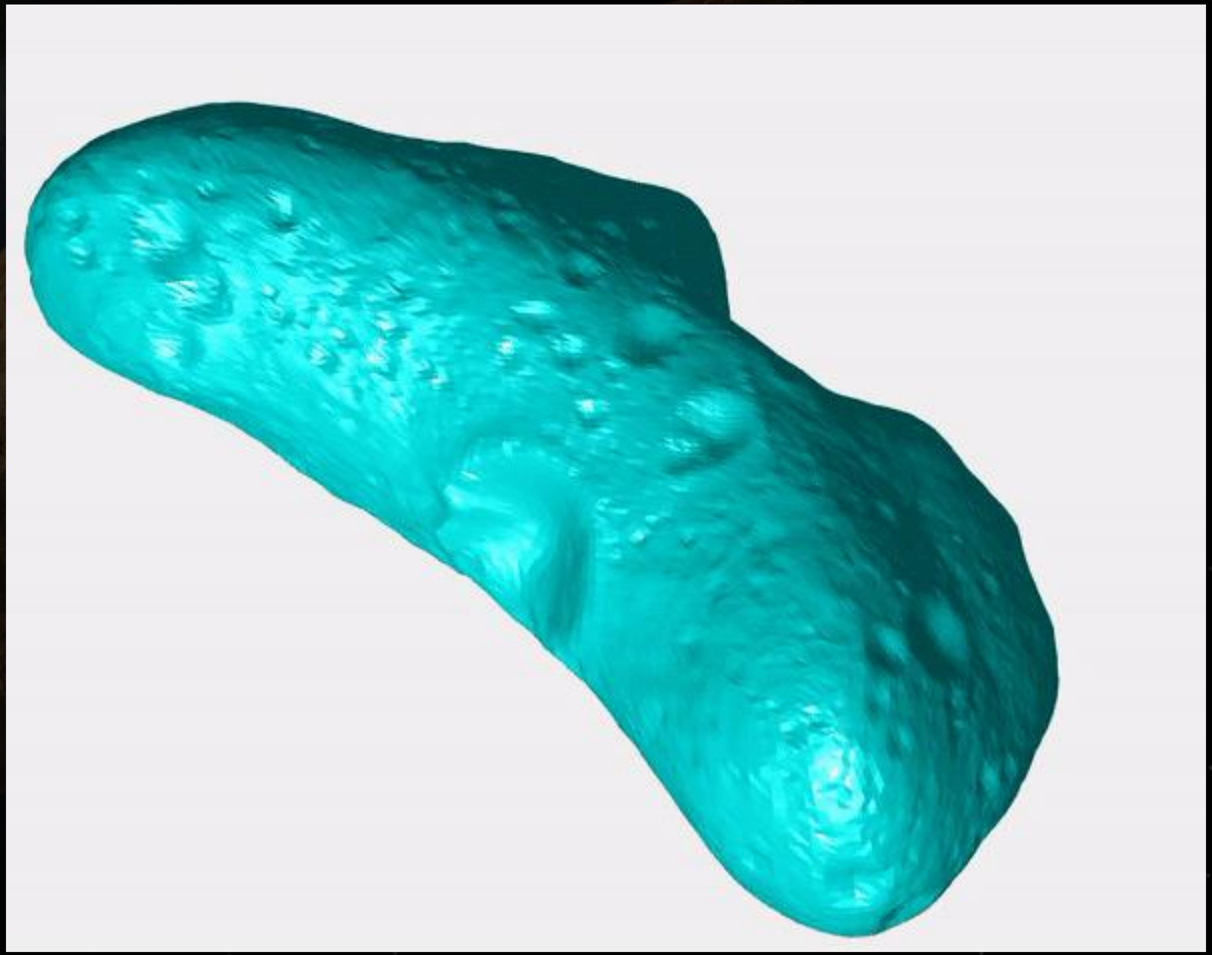


Credit: Nasa's OsirisRex Mission

Scientific Objectives

Understanding the Tidal Force Effects

- *Requirement:* Investigate/Observe Apophis' surface during the pre-flyby during and post-flyby
- *Purpose:* To understand tidal force effects on the asteroid during the close encounter
- *Techniques:* Utilizing LIDAR measurements and high-resolution camera images.

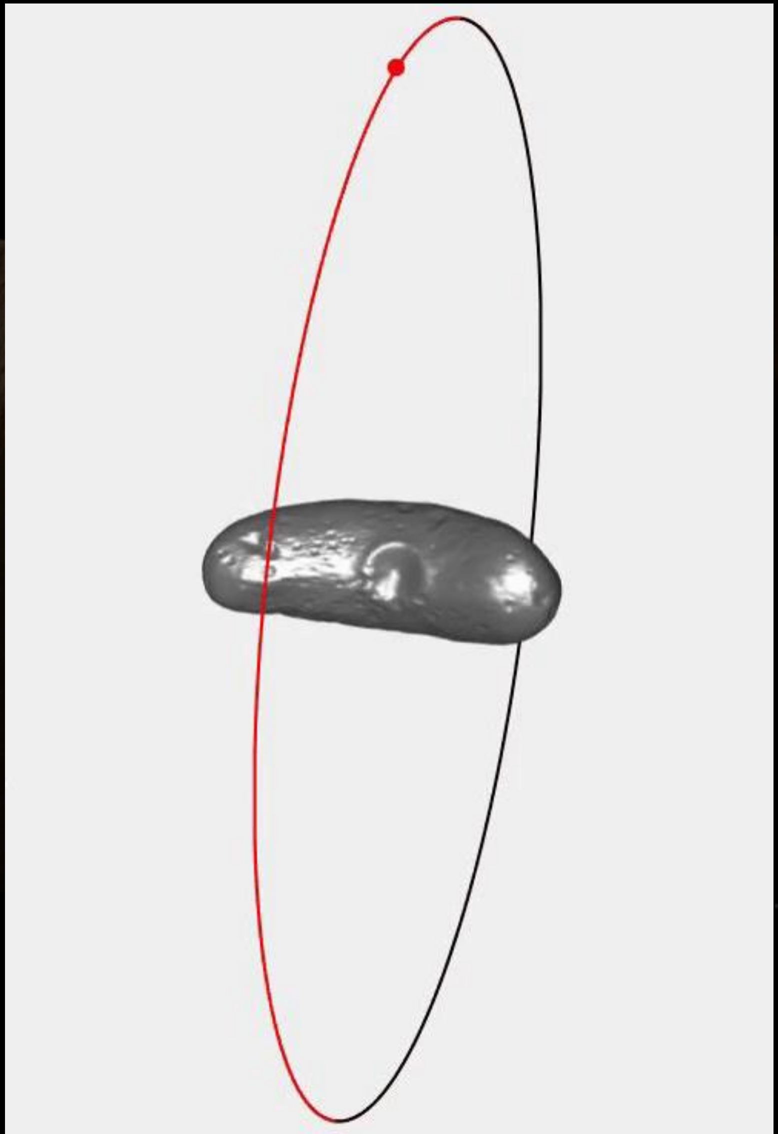


Credit: Dr. Paul Sava

Technology Demonstration Objectives

Fly-By Vibration Measurement with a single LDV

- *Requirement:* Measuring the magnitude of seismic vibrations due to tidal forces on the Apophis during pre-flyby, flyby and post-flyby
- *Purpose:* To understand whether tidal force vibration can be measured by LDV
- *Techniques:* Utilizing LDV and comparison of the data obtained at flyby and pre/post-flyby.



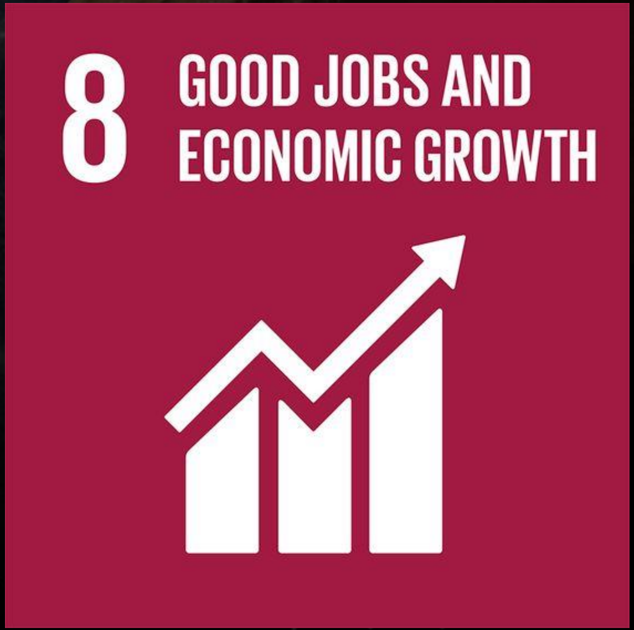
Credit: Dr. Paul Sava

Attracting Interest on Space Studies

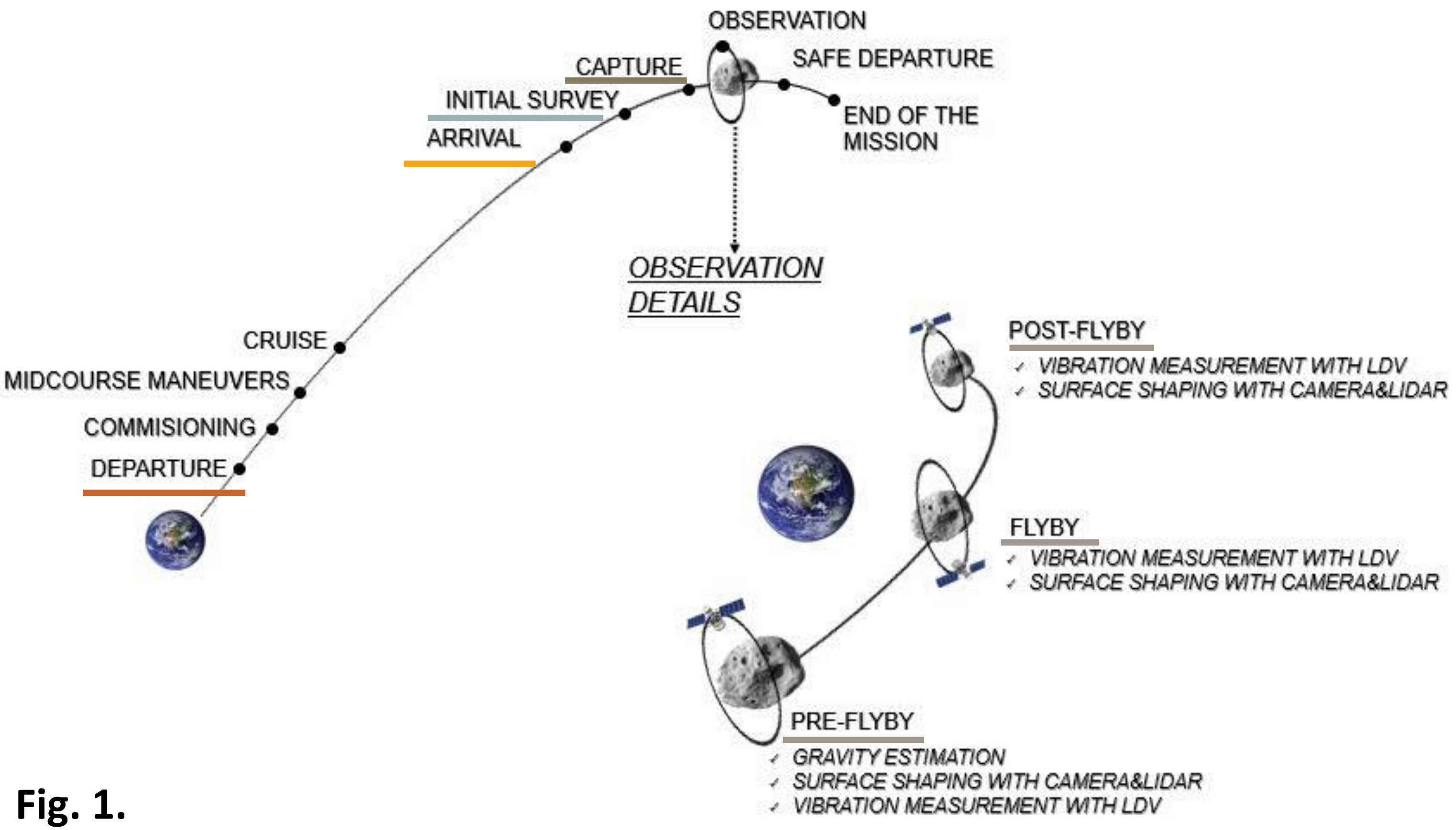
Social Objectives

- The proposed project can be carried out in cooperation with space agencies and universities to raise awareness of the space science and exploration.
- Especially in Turkey, these kind of projects can motivate lots of young people and children and foster the interest in space exploration and science.
- Proving that high impact scientific space missions is possible with low-cost micro-satellite and capacity building in Turkey for qualified human resource development.

Credit: United Nations



CONCEPT OF OPERATIONS, MISSION DESIGN AND EXPERIMENTAL CONCEPT: CONOPS DIAGRAM



	DATE/DURATION
DEPARTURE	20.04.2028
ARRIVAL	08.03.2029
INITIAL SURVEY	30 DAYS
CAPTURE	07.04.2029
PRE-FLYBY OBSERVATION	5 DAYS
FLYBY OBSERVATION	3 DAYS
POST-FLYBY OBSERVATION	5 DAYS

Fig. 1.

ΔV AND TOF VERSUS ARRIVAL DATE

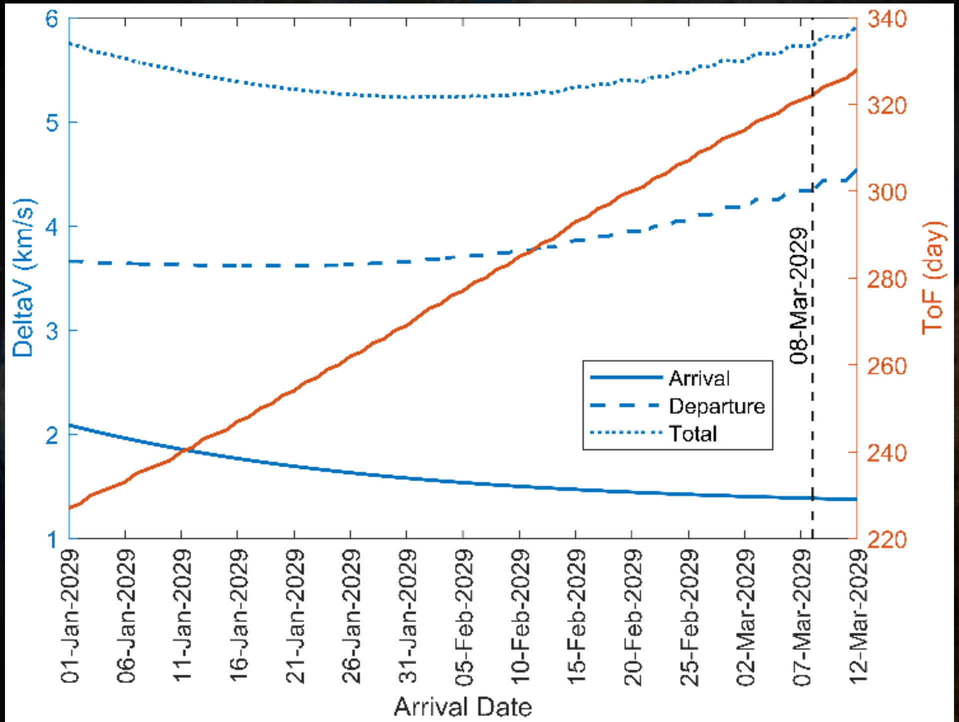


Fig. 2.

- Lambert algorithm is used.
- Different departure and arrival dates are examined.
- Optimum departure date is determined for the chosen arrival/rendezvous date.

LAUNCH, CRUISE AND ARRIVAL PHASE

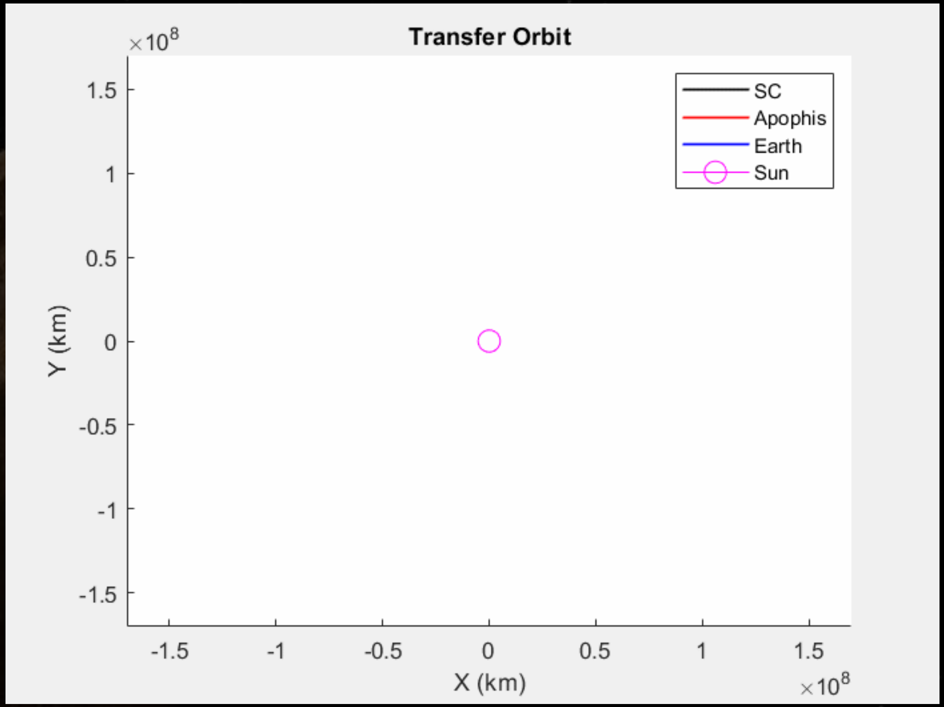


Fig. 3.

- Gravity of Sun and planets, solar radiation pressure, relativistic correction are considered.
- Transfer duration is 322 days.
- Rendezvous at 20 km distance.

INITIAL SURVEY PHASE

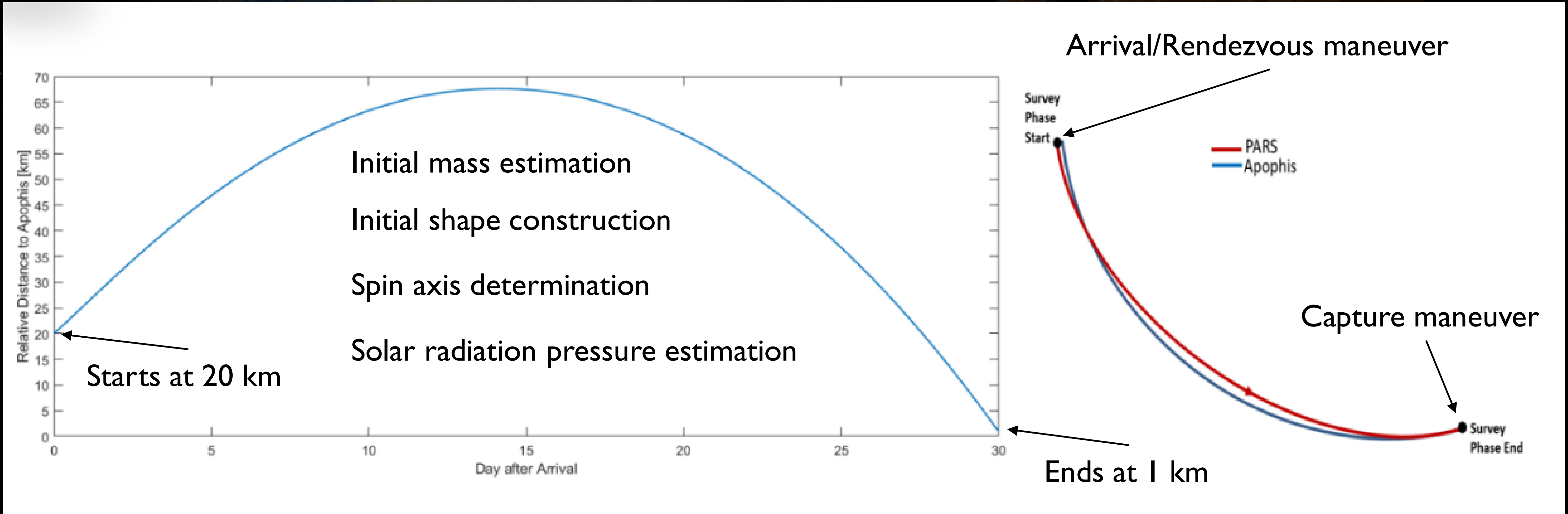


Fig. 4.

MISSION ORBIT

- 1 km circular polar orbit.
- Orbital period is 1.7 days.
- Rotational period of Apophis 1.3 days

- Eclipse occurs 3 times during the mission orbit.
- Longest eclipse duration is 2.3 hours.
- Safe mode (Minimum power consumption), battery

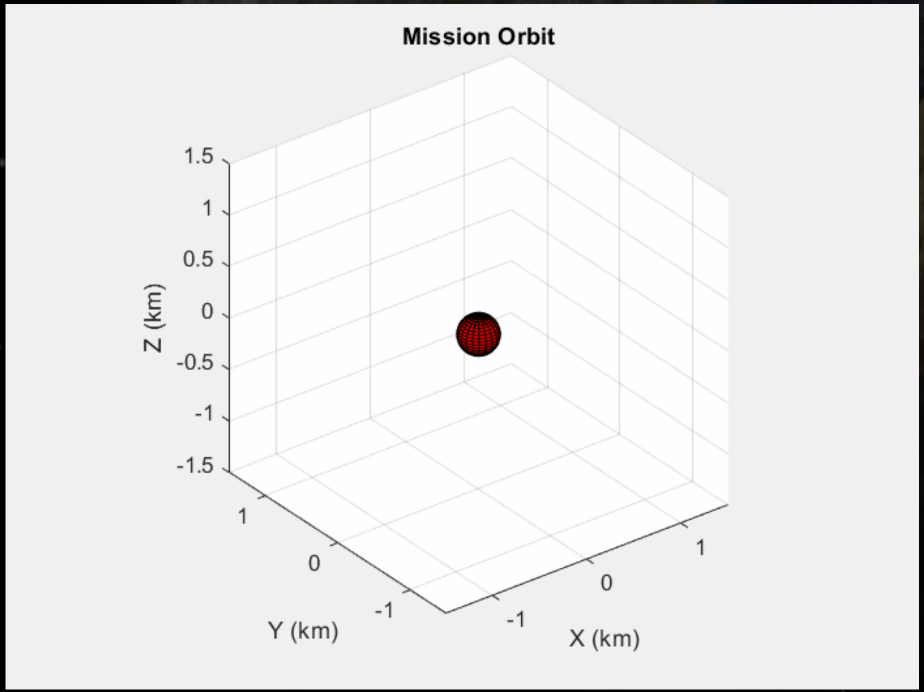


Fig. 5.

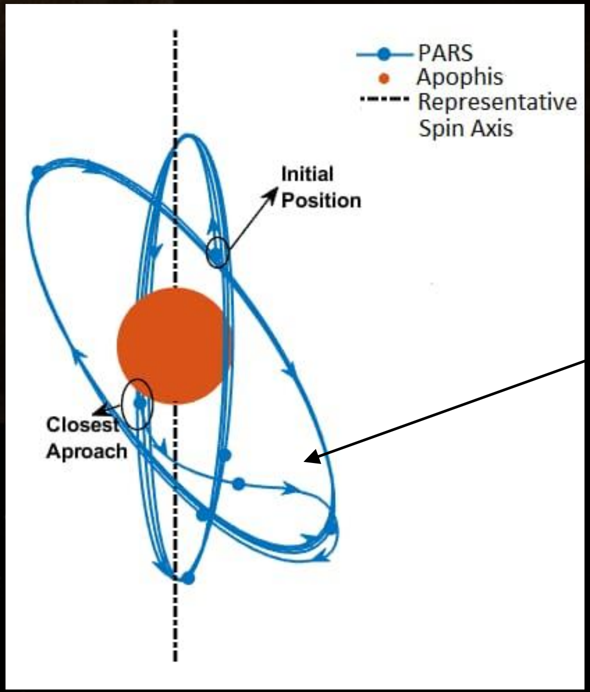


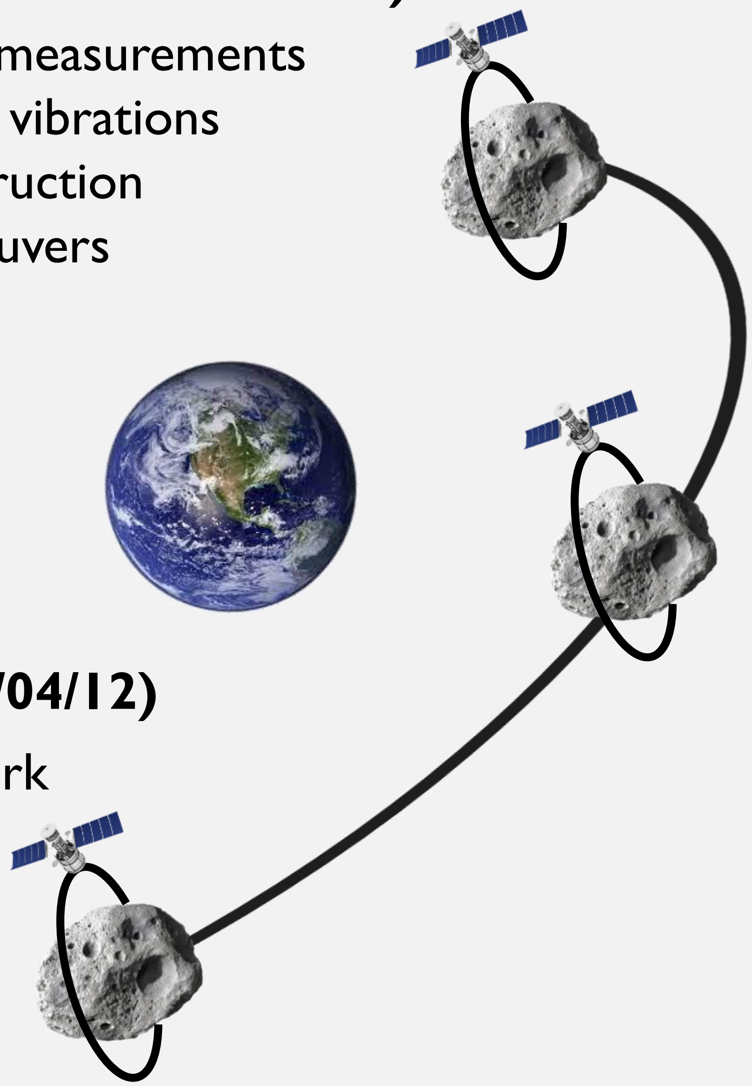
Fig. 6.

- Change in the orbit due to gravity of Earth during the closest approach
- Station keeping is highly important!

SCIENTIFIC OBSERVATIONS

POST-FLYBY (2029/04/15-2029/04/20)

- LDV will keep taking measurements
- Expected decrease in vibrations
- Detailed shape construction
- Station keeping maneuvers



FLYBY (2029/04/12-2029/04/15)

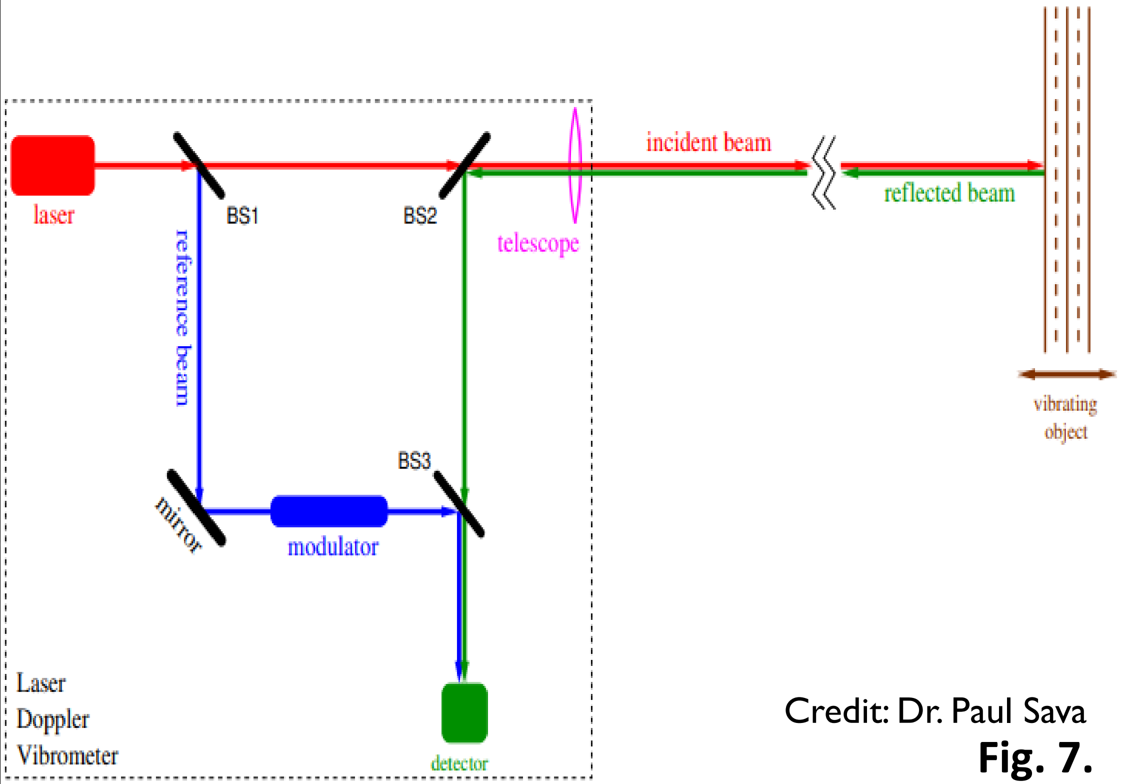
- Inside the Earth’s Sphere of Influence
- LDV will keep taking measurements
- Expected increase in vibrations
- Detailed shape construction
- Station keeping maneuvers

PRE-FLYBY (2029/04/07-2029/04/12)

- First time in space, LDV will work
- Reference measurements
- Precise mass estimation
- Detailed shape construction
- Station keeping maneuvers

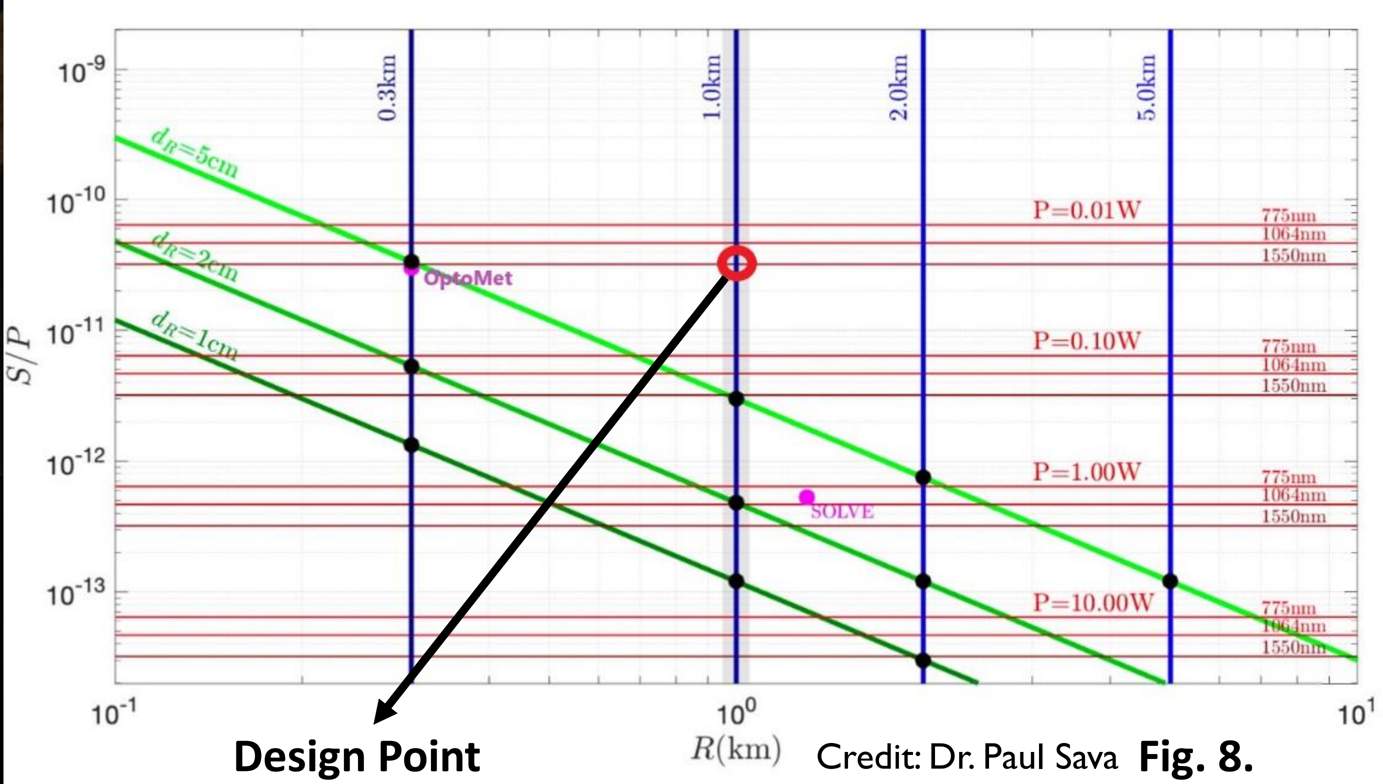
KEY PERFORMANCE PARAMETERS
LASER DOPPLER VIBROMETER (LDV)

- LDV Lens Diameter
- LDV Required Power
- LDV Mass
- LDV Dimensions



Credit: Dr. Paul Sava

Fig. 7.



Credit: Dr. Paul Sava **Fig. 8.**

SPACECRAFT SYSTEM OVERVIEW

- 50cm x 50cm x 50cm size with 2 foldable solar arrays
- 91.266 kg launch mass and 45.852 kg dry mass
- Payloads
  - LDV, Optical Camera and LIDAR
- ADCS (3 axis control with 0.02° accuracy)
  - 6-Sun sensors, Star tracker, IMU
  - 4-reaction wheels, 8-attitude thrusters
- High Performance Green Propulsion System
- Power
  - ~350W power generation
  - 125Wh Li-ion Battery
- Supported modes: Observation, Communication, Orbit Correction, Safe
- Estimated Cost: 35M$

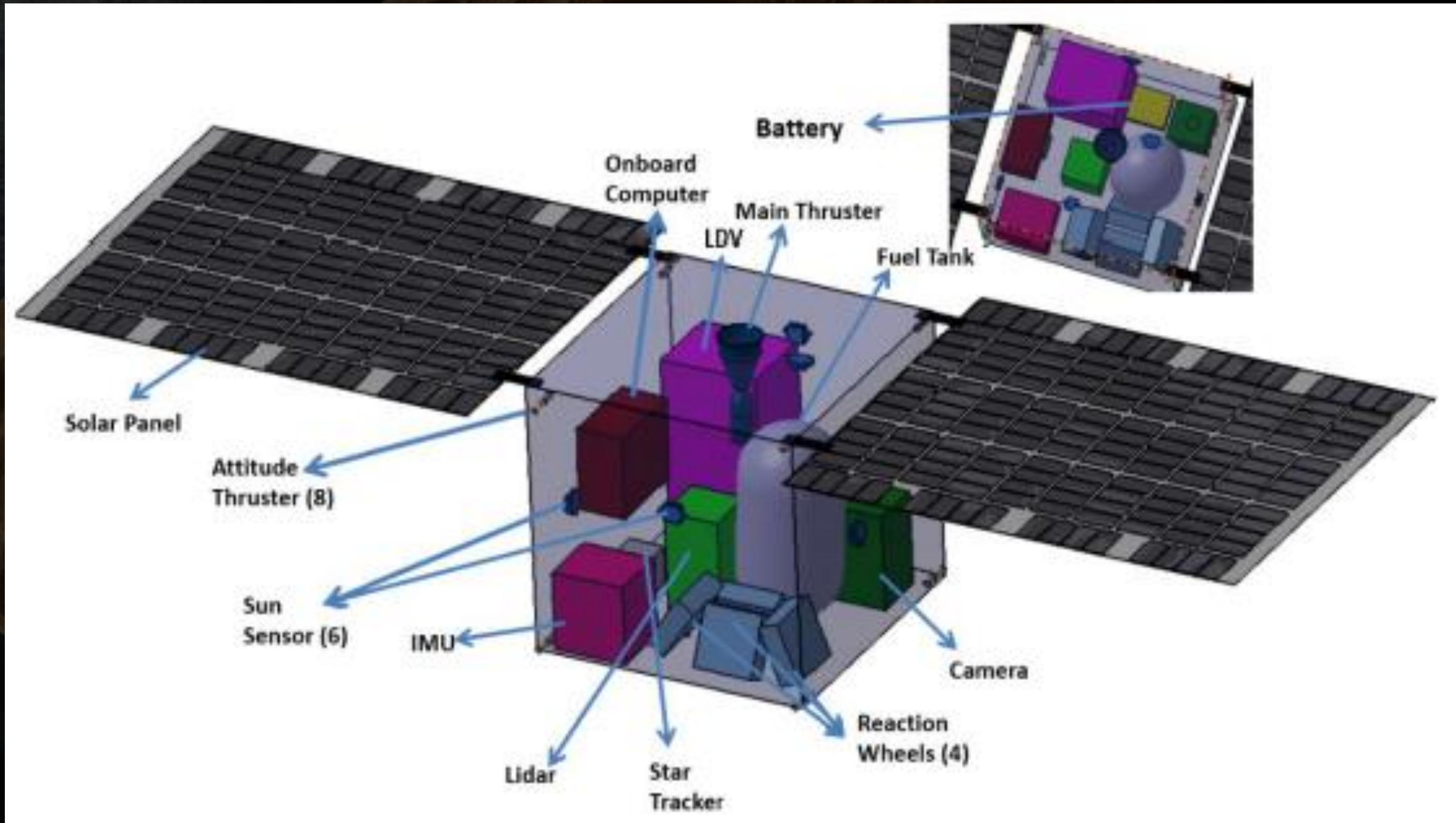
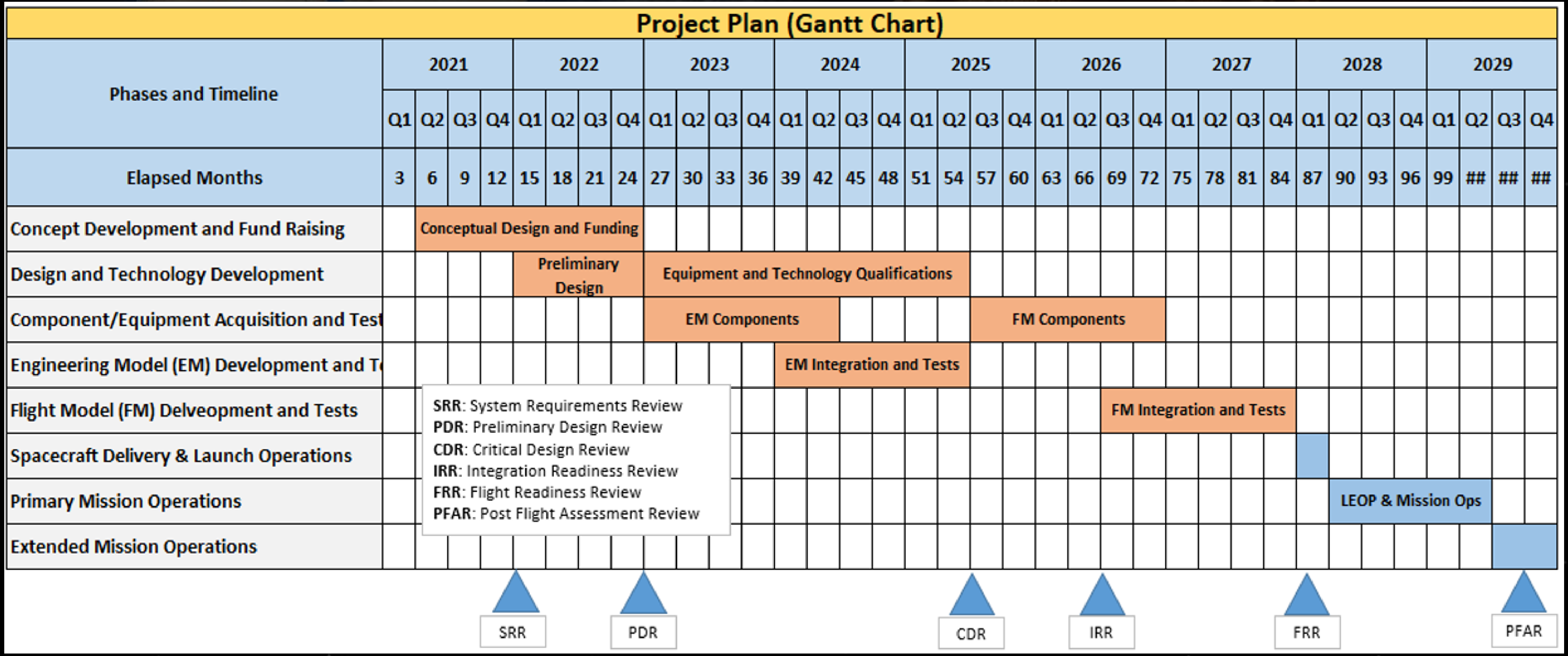


Fig. 9.

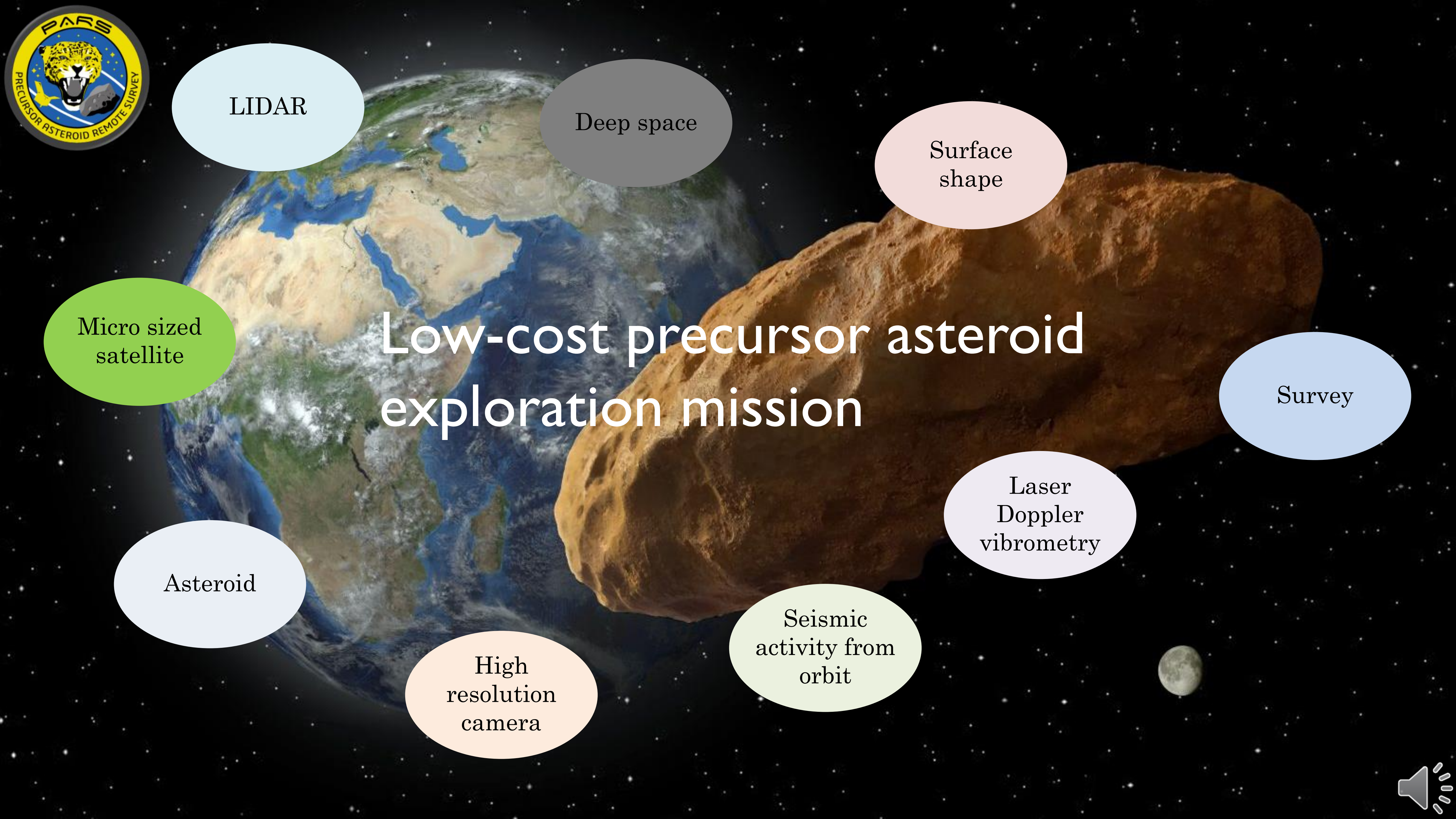
MISSION RISKS

PAYLOAD FAILURE	Potential effects →	Lowers the scientific outcomes of the mission	Mitigation strategy →	Careful testing of LIDAR and LDV Using a flight proven LIDAR (e.g. HAYABUSA2) to increase reliability
MAIN THRUSTER FAILURE	Potential effects →	Not arriving Apophis at desired time, crashing to Apophis, leaving the mission orbit	Mitigation strategy →	Orbit maneuver by attitude thrusters if main thruster fails.

GANTT CHART


Project Plan (Gantt Chart)
Phases and Timeline
2021
2022
2023
2024
2025
2026
2027
2028
2029
Q1 Q2 Q3 Q4
Elapsed Months
3 6 9 12 15 18 21 24 27 30 33 36 39 42 45 48 51 54 57 60 63 66 69 72 75 78 81 84 87 90 93 96 99 ## ## ##
Concept Development and Fund Raising
Design and Technology Development
Component/Equipment Acquisition and Test
Engineering Model (EM) Development and T
Flight Model (FM) Delveopment and Tests
Spacecraft Delivery & Launch Operations
Primary Mission Operations
Extended Mission Operations
Conceptual Design and Funding
Preliminary Design
Equipment and Technology Qualifications
EM Components
FM Components
EM Integration and Tests
FM Integration and Tests
LEOP & Mission Ops
SRR: System Requirements Review
PDR: Preliminary Design Review
CDR: Critical Design Review
IRR: Integration Readiness Review
FRR: Flight Readiness Review
PFAR: Post Flight Assessment Review
SRR
PDR
CDR
IRR
FRR
PFAR

Low-cost precursor asteroid exploration mission

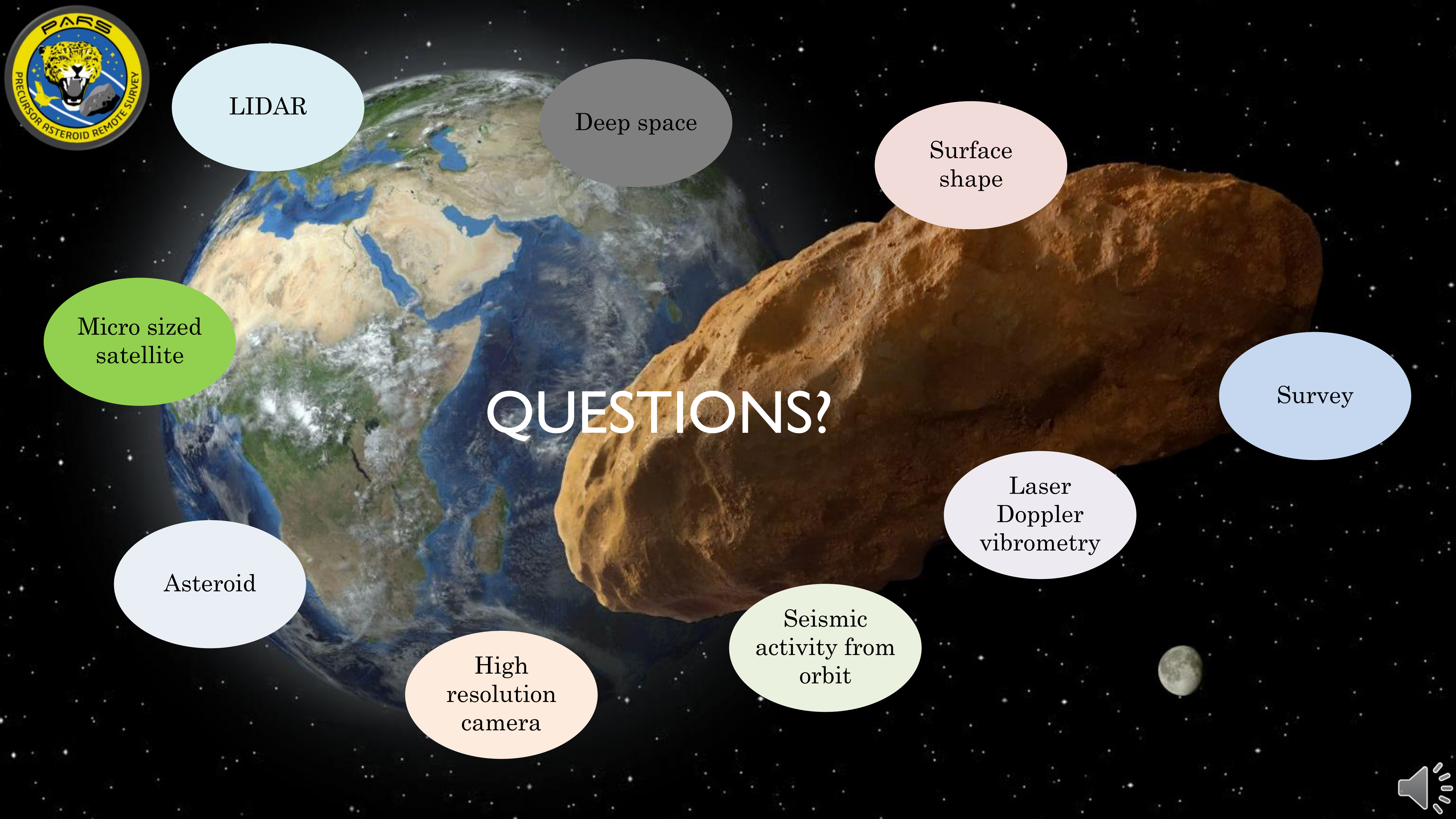


So Long and Thanks for All the Fish

Pars Team Advisors

Burak YAGLIOGLU

H. Ersin SOKEN


LIDAR
Deep space
Surface shape
Micro sized satellite
QUESTIONS?
Survey
Laser Doppler vibrometry
Asteroid
High resolution camera
Seismic activity from orbit

APPENDIX

SUBSYSTEMS MASS AND POWER BUDGET

Instruments and Equipments	Mass (kg)	Size (mxmxm)	Power Consumption (W)
Payload			
Fibertek 2U LIDAR	2	0.1x0.1x0.2	14.3
Simera TriScape100 Camera	1.2	0.098x0.098x0.176	6
Optomet NOVA SWIR LDV	11.6	0.380x0.180x0.148	27
Power Systems			
ABSL Li-Ion Battery	0.98	0.098x0.086x0.060	N/A
2 × DHV Solar Panel	6	0.85x0.70	N/A
ADCS Systems			
4 × Blue Canyon RW1	3 (4 Reaction Wheels)	0.11x0.11x0.038	9 (each)
Innalabs Polaris IMU	2	0.112x0.132x0.145	10
Adcole Space Star Tracker	0.282	0.055x0.065x0.070	3
6 × Solar MEMS Sun Sensor	0.150	0.040x0.030x0.012	0.036 (each)
8 × Bradford 100mN Thruster	0.32	Length: 0.055	8 (each)
Bradford 22N Thruster	1.1	Length: 0.26	50
HPGP Propellant Budget	45.414		
Comm. & Data Handling			
PROCYON's Transponder	6.60	N/A	85
SOI CPU On-Board Computer*	1.62	0.156x0.153x0.085	10
Structure Margin	9		

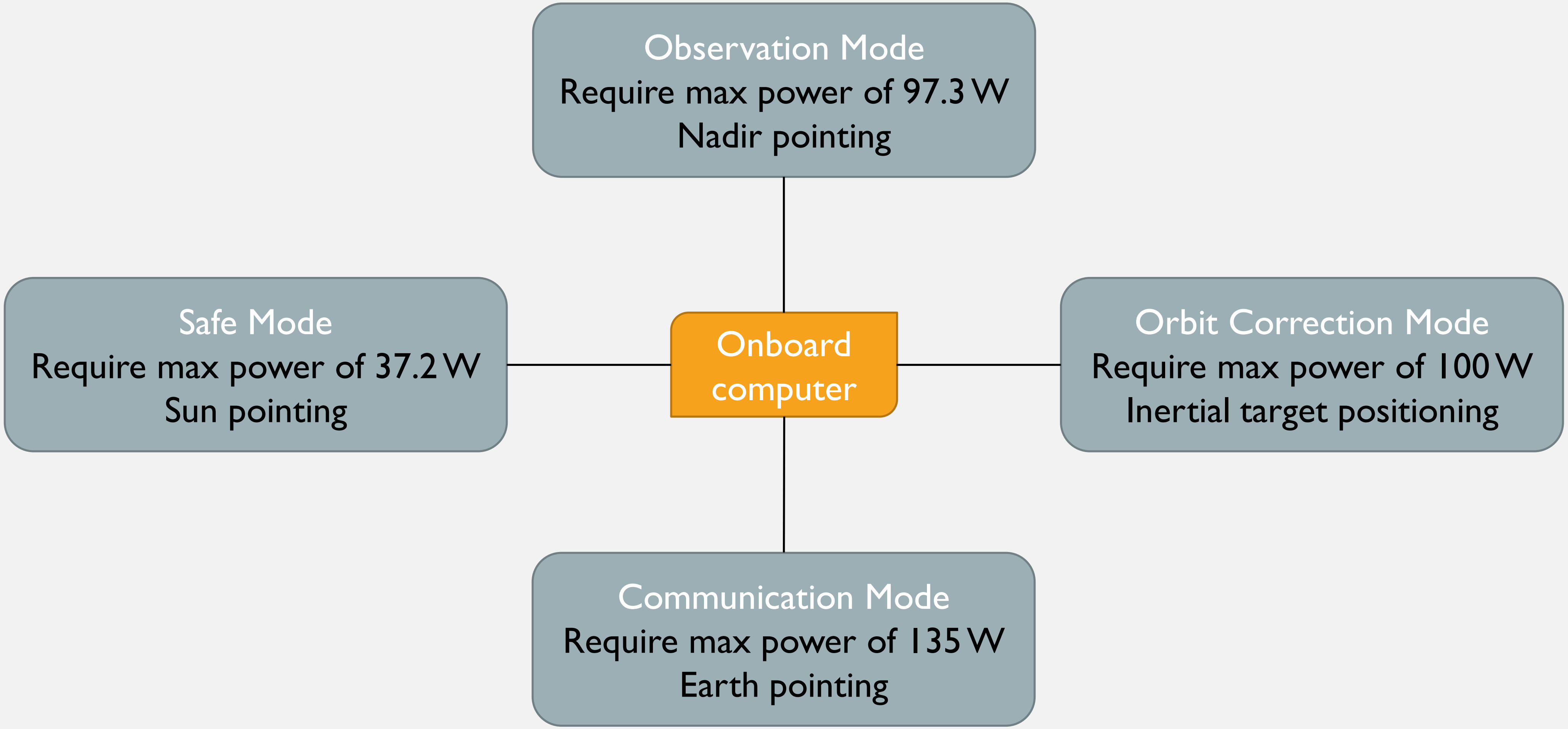
APPENDIX

KEY MISSION PARAMETERS

Spacecraft	**Size: 50 cm × 50 cm × 50 cm + 2 Folded Solar Array Panels (launch configuration), Launch Mass: 91.266 kg, Dry Mass: 45.852 kg**
Design Life Span	Launch: April 2028, Approach to Apophis: March 2029, Observation Period: 40-50 days
AOCS	Sensors: 6x Sun Sensors, Star Tracker, IMU (Inertial Measurement Unit), Relative Navigation: LIDAR and Optical Camera, Actuators: 4x Reaction Wheels, 8x Attitude Thrusters\\ Pointing accuracy: 0.02°
Propulsion	High Performance Green Propulsion (HPGP), Propellant: LMP-103S
Power	Solar Arrays with triple-junction GaAs and 3s4p 11.6Ah 125Wh Li-ion Battery
Communication	X-band (for deep space mission), Antenna: HGA, MGA, LGA×2 (for uplink), LGA×2 (for downlink), Output Power: >15 W, 30%
Estimated Cost	$35M

APPENDIX

MAIN OPERATION MODES



DATA BUDGET

APPENDIX

- Data collected from the camera

  1 shot is 1024x768 resolution x 10bit = 7864320 bit = 0.9375 MB

  1 shot in every hour for 22 hours in a day = 22 images/day

  Total data collected from the camera in the mission: 12 days x 22 images/day x 0.9375 MB = 247.5 MB

- Data collected from the LDV: 20MB/h for continuous data collection

  1 min. open in every hour for 22 hours in a day = 20MB/h x 1/60 x 22 hours = 7.33 MB

  Total data collected from the LDV in the mission: 12 days x 7.33 MB = 88 MB

- Data collected from the LIDAR: 20MB/h for continuous data collection

  1 min. open in every hour for 22 hours in a day = 20MB/h x 1/60 x 22 hours = 7.33 MB

  Total data collected from the LIDAR in the mission: 12 days x 7.33 MB = 88 MB

- Total data collected from the payloads: 247.5+88+88 = 423.5 MB
- We have 16kbps data upload rate in average, having 8 hours communication at the end of mission provides 230400 kb/day = 28.125MB/day.

  Required #days to upload all data = 423.5/28.125 = 15.05 days

- For daily communication of 2 hours, it is required to send Spacecraft telemetry data
  - Necessary data collected in a day: 1kbps SC TM for 24 hours = 86400 kb
  - Upload capacity in a day: 16kbps upload rate for 2 hours = 115200 kb
  - We can manage the send all necessary data and some data collected from payloads can be also uploaded.

SMALL SATELLİTE COST MODEL (FROM SMAD)
ALL COSTS ARE WRİTTEN İN K$

TOTAL ESTİMATED PROGRAM COST: ~35 M$
(EXCEPT LAUNCH AND GS NETWORK)

	EM	FM
Structure	790	790
Thermal	340	340
ADCS	2240	2240
Elecrical Power System	3450	3450
Propulsion	1500	1500
TT&C	1200	1200
Command & Data Handling	850	850
Spacecraft Bus Total Cost	10370	10370
Integration, Assembly & Test		1451,8
Flight Software		2750
LDV, LIDAR, Camera	2074	4148
Project Management & System Engineering		2074
Launch & Orbital Ops Support		518,5
Ground Support Equipment		725,9
Total Program Cost for 1 FM (k$)		22038,2
TOTAL PROGRAM BUDGET (k$)		34482,2

APPENDIX