CubeSat Constellation Architecture to Support Space-Based Property Claims

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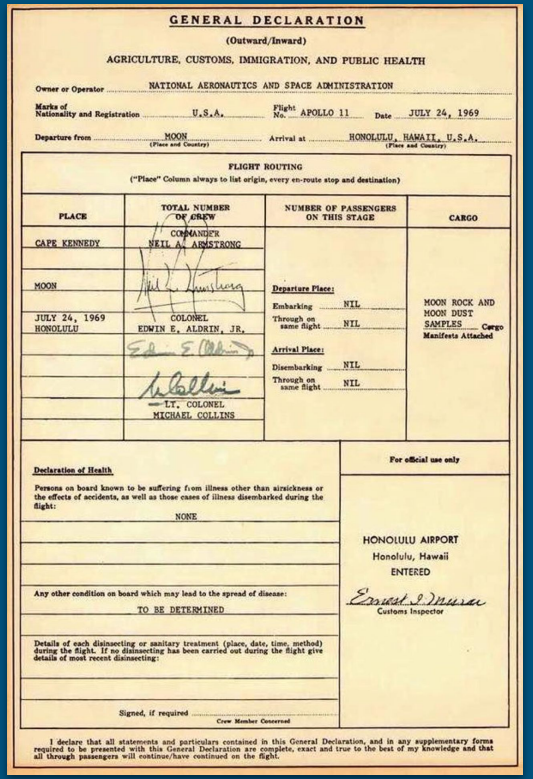
Challenges

- Property Ownership and Usage Rights in Space (Int'l Law and Military/Defense)
- Historical Norms
  - Societal and Economic
- Registration (e.g., UN Registry for Objects in Space)



GENERAL DECLARATION

(Outward/Inward)

AGRICULTURE, CUSTOMS, IMMIGRATION, AND PUBLIC HEALTH

Owner or Operator: NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

Marks of Nationality and Registration: U.S.A. Flight No.: APOLLO 11 Date: JULY 24, 1969

Departure from: MOON (Place and Country) Arrival at: HONOLULU, HAWAII, U.S.A. (Place and Country)

FLIGHT ROUTING

("Place" Column always to list origin, every en-route stop and destination)

PLACE	TOTAL NUMBER OF CREW	NUMBER OF PASSENGERS ON THIS STAGE	CARGO
CAPE KENNEDY	COMMANDER NEIL A. ARMSTRONG		
MOON		Departure Place: Embarking NIL; Through on same flight NIL	MOON ROCK AND MOON DUST SAMPLES Cargo Manifests Attached
JULY 24, 1969 HONOLULU	COLONEL EDWIN E. ALDRIN, JR.	Arrival Place: Disembarking NIL; Through on same flight NIL	
	LT. COLONEL MICHAEL COLLINS		

Declaration of Health

Persons on board known to be suffering from illness other than airsickness or the effects of accidents, as well as those cases of illness disembarked during the flight: NONE

Any other condition on board which may lead to the spread of disease: TO BE DETERMINED

Details of each disinsecting or sanitary treatment (place, date, time, method) during the flight. If no disinsecting has been carried out during the flight give details of most recent disinsecting:

Signed, if required ..... Crew Member Concerned

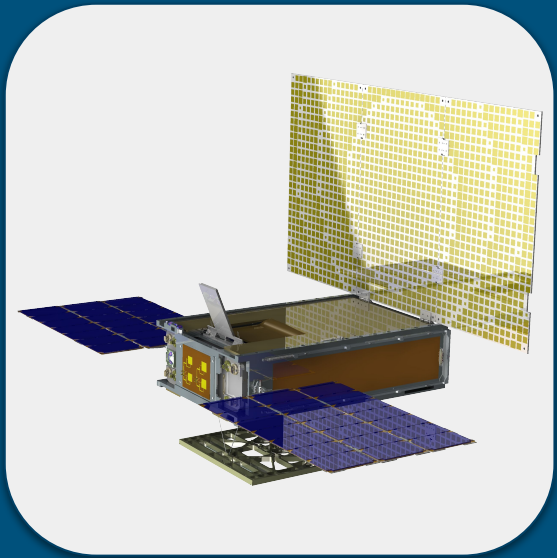
For official use only

HONOLULU AIRPORT
Honolulu, Hawaii
ENTERED
Ernest I. Miura
Customs Inspector

I declare that all statements and particulars contained in this General Declaration, and in any supplementary forms required to be presented with this General Declaration are complete, exact and true to the best of my knowledge and that all through passengers will continue/have continued on the flight.

Missions Involving Secondary CubeSat Deployments

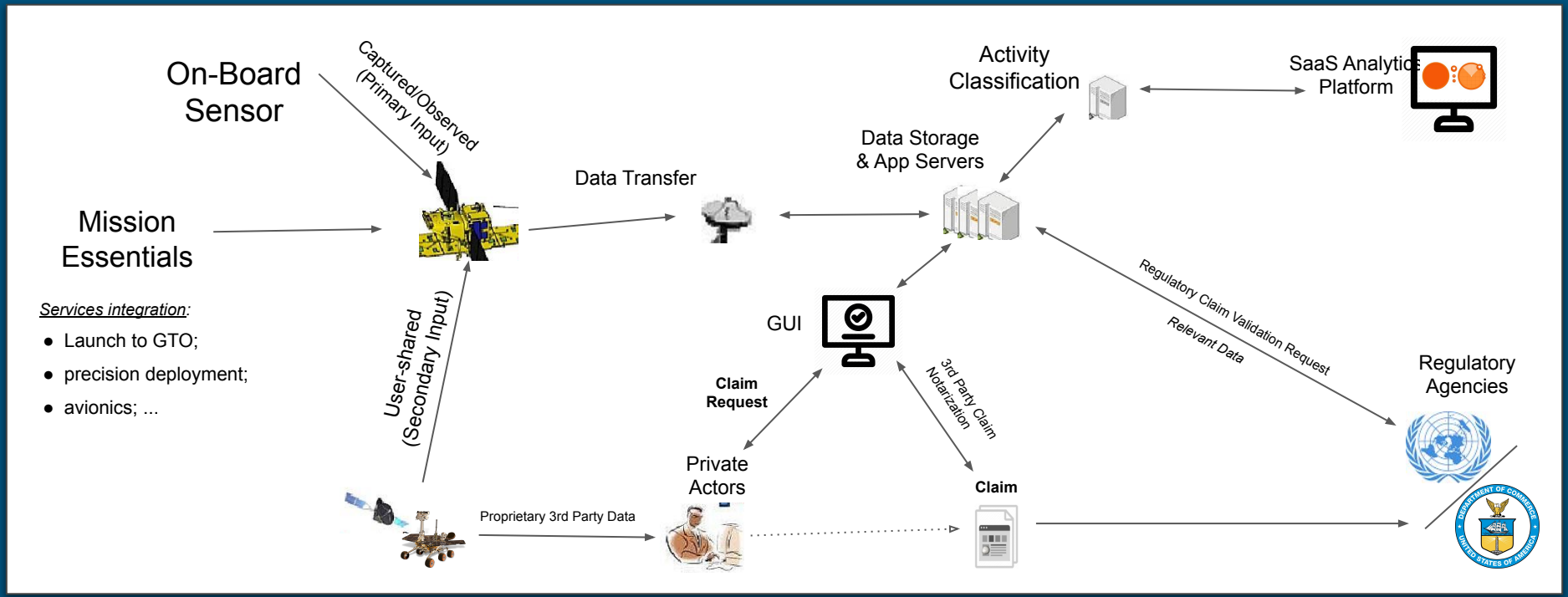
- Psyche
- Proteus
- BASiX
- MarCO*



Mission Objectives

- ***Deployment*** of ‘Beacons’ to Small-Body Orbit
  - Sensory Instrumentation ‘***Geo’locating*** and In-Space Activity ***Capture***
- ***Integration*** with Service Providers
- ***Collection*** comprising ‘universal cadastre’
- ***Cooperation*** with Domestic and International Regulatory Agencies

System Architecture



Mission

Key Planning Steps and Events Sequence

I. Small-body, destination selection;

II. Launch window selection;

... ;

... ;

... ;

... ;

... ;

... ;

... .

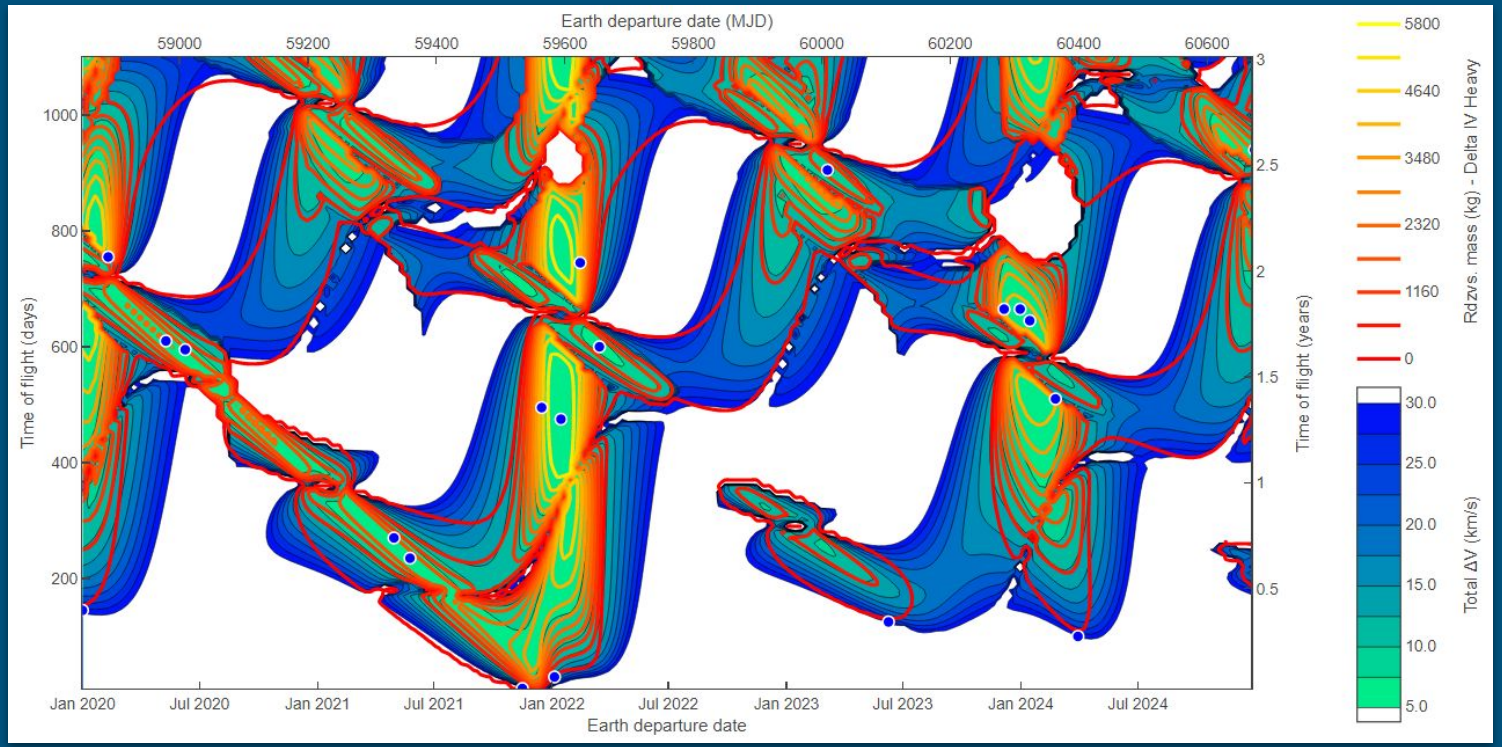
Mission

Small-Body Selection

4660 Nereus (1982 DB)	
Δ*v* (km/s)	**4.985**
Taxonomy	**C, X, E**
Spin Period (hours)	**15.16**
Synodic Period (years)	**2.225**
Orbit Condition Code	**0**

Mission

Launch Windows for 4660 Nereus (1982 DB)



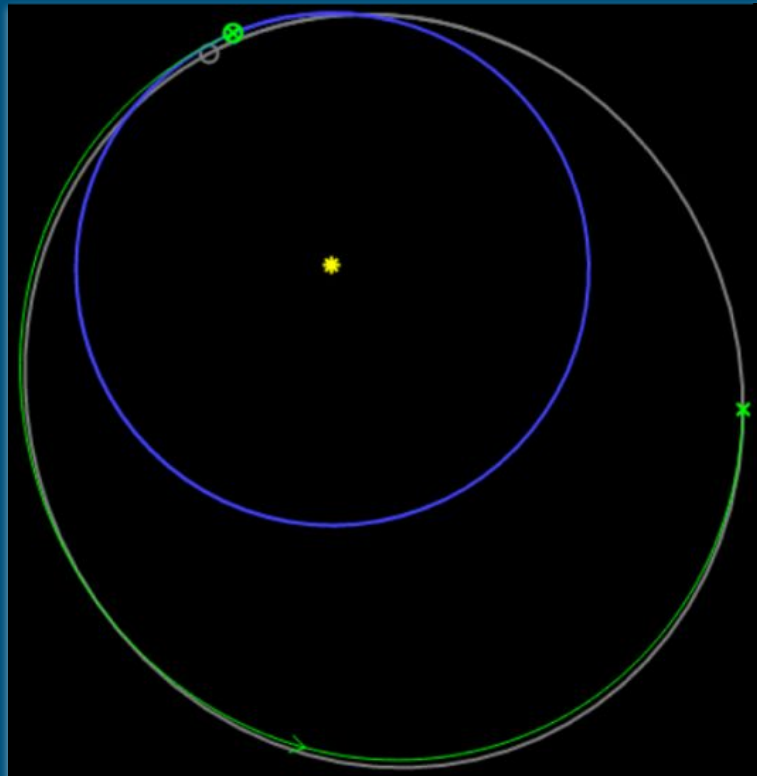
Mission

Key Planning Steps and Events Sequence (*continued*)

I. Selection of small-body, probe destination;
II. Select launch window;
III. Launch to GEO;
IV. Payload deployment;
V. CubeSat travels toward rendezvous with small-body;
VI. CubeSat positioning in orbit around small-body;
VII. Data acquisition;
VIII. Relays to larger satellite receiver; and
IX. Continuous data acquisition, encoding, and relays.

Mission

Trajectory Itinerary



4660 Nereus (1982 DB)

SPK-ID	2004660	Orbit Condition Code	0
Absolute Magnitude	18.2	Size	330 m
Semi-major axis	1.486 AU	Eccentricity	0.359
Inclination	1.45°		

Trajectory Itinerary

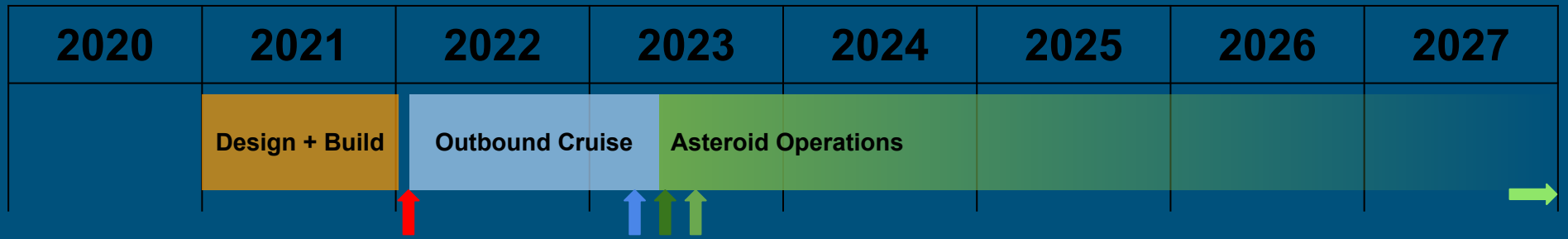
	Date	ΔV	
Earth Departure	Jan-13-2022	4.07 km/s	C3 = 19.3 km^2/s^2 DLA = 6°
1.31-yr transfer			
Asteroid Arrival	May-08-2023	586 m/s	
1.31-yr total mission		587 m/s 4.66 km/s	post-injection ΔV total ΔV

Solar range:	0.98 - 1.98 AU	Earth range:	0 - 2.94 AU

JPL Small-Body Database Browser

Mission

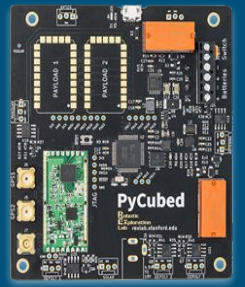
Full Timeline

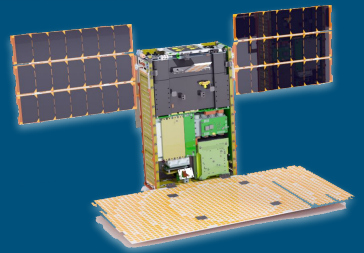


- Launch: Jan 2022
- Asteroid acquisition and approach maneuvers
- Maneuvers to reach asteroid orbit
- In-orbit observations and comms
- In-orbit servicing (*ongoing*)

Hardware

- Dispenser, Housing for CubeSat Constellation
- Locker
  - CubeSat Bus
    - Single-Board Computer and Memory
    - Thermal Radiator and Radiation Shielding
    - Solar Panels
    - Electric Propulsion System
    - Iris V2 CubeSat Deep-Space Transponder (IRIS), Omni-Directional UHF Antenna, and High Gain Reflectarray Antenna
    - Van Atta Reflectors
  - Sensors
    - CMOS Cameras
    - Laser Altimeter and Star Tracker





Software

- **Off-the-shelf**:
  - Dispenser Timing/Precision Deployment and Propulsion
  - Power Management
  - Avionics, Attitude Control, and Station-Keeping
  - Advanced RF Analytics
  - Relay Encoding and Timing
- **In-house**:
  - Data Capture, Handling, and Logging/Storage
  - Activity Classifier
  - Secure Encryption and Storage Distribution

Comms

- Secure Transmissions Over Long Distances
  - Sacrifice Timeliness for Precision, Reliability
- Interoperable with Larger Satellite Communications Infrastructure

- Data Storage Distribution: Portion Kept in Space, Portion Sent to Earth-Based Servers

Regulatory Concurrence

- *Main Objective*: Legitimize In-Space Property Ownership & Usage Rights
- Precise Location & Activity Data, Validating Legitimacy of Third-Party Claims
- Service provider for State and Non-State actors
- Digitally Connected with Appropriations Agencies at the International and Domestic Levels

THE LAND REGISTRATION ACT
(No. 3 of 2015, section 105)
THE REGISTERED LAND ACT
(Chapter 300) (REPEALED)

Title Deed

Title Number

Approximate Area

Registry Map Sheet No.

This is to certify that

is (are) now registered as the absolute proprietor(s) of the land comprised in the above-mentioned title, subject to the entries in the register relating to the land and to such of the overriding interests set out in section 28 of the Land Registration Act (No. 3 of 2012) as may for the time being subsist and affect the land.

GIVEN under my hand and the seal of the

District Land Registry

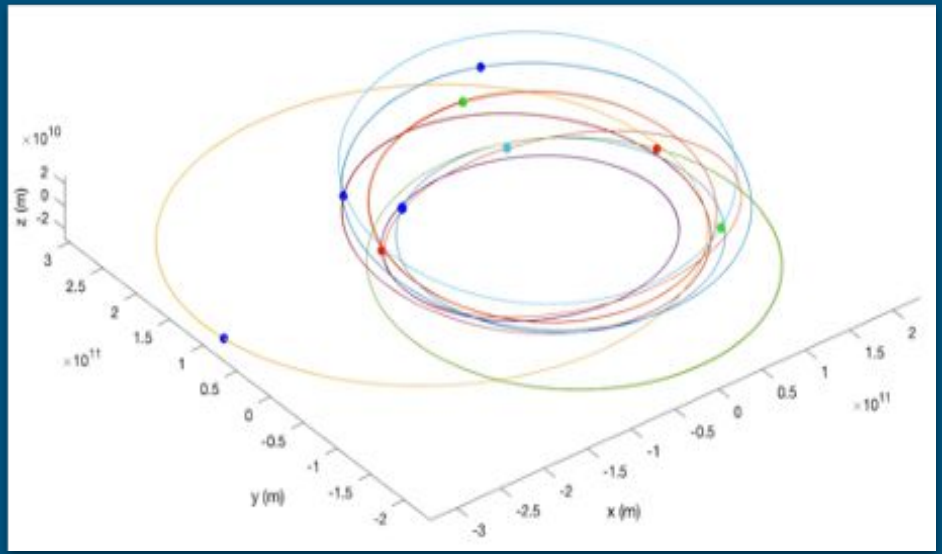
this 6th day of

20 14

Land Registrar

Further Investigation

- Optimization Algorithm for *Constellation-Scale Deployment*
- Comms Upgrades
- Sensors Upgrades
- Modularity



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