DiskSat: Demonstration Mission for a Two-Dimensional Satellite Architecture

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CubeSats and the Small-Satellite Revolution

The power of “containerization”

- CubeSats revolutionized the small satellite industry through containerization, just as containerization revolutionized terrestrial shipping
  - *Containerization simplifies the interface and protects the host, enabling inexpensive rideshare*
  - *In 20 years, over 1100 CubeSats have been launched worldwide*
  - *CubeSats have flown on at least 20 different launch vehicle types*
- CubeSats are rigidly constrained by the volume of the container
  - Limits on power and aperture, even with complex deployables

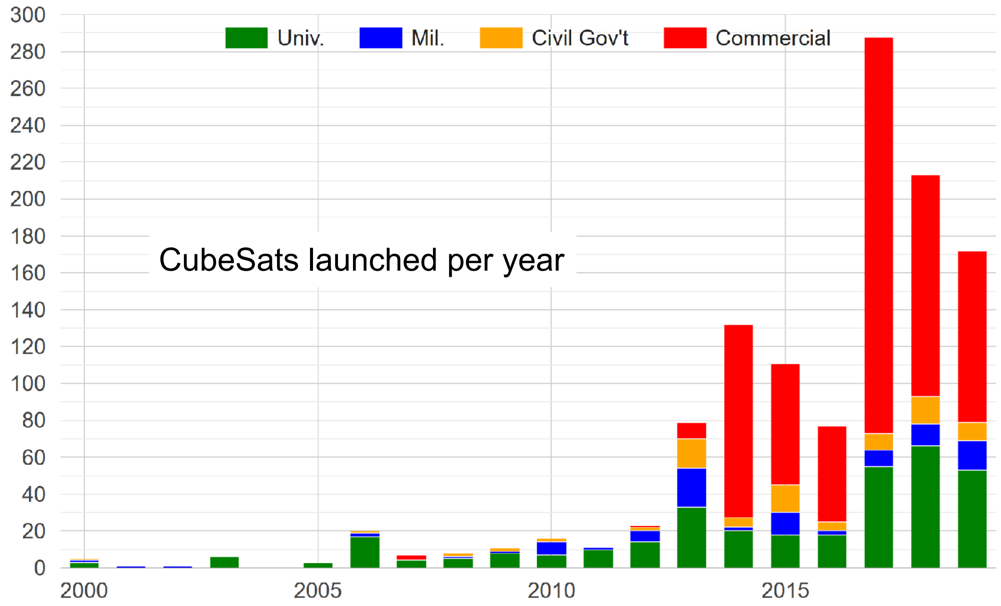
Containerization of terrestrial shipping

Images courtesy U.S. DOT

Containerization
→ Reduced launch risk and simplified interface
→ Inexpensive rideshare
→ Frequent and flexible launch
→ Commercial expansion
→ Mass production

PSSCT-2 leaving dispenser on STS-135

Image courtesy NASA



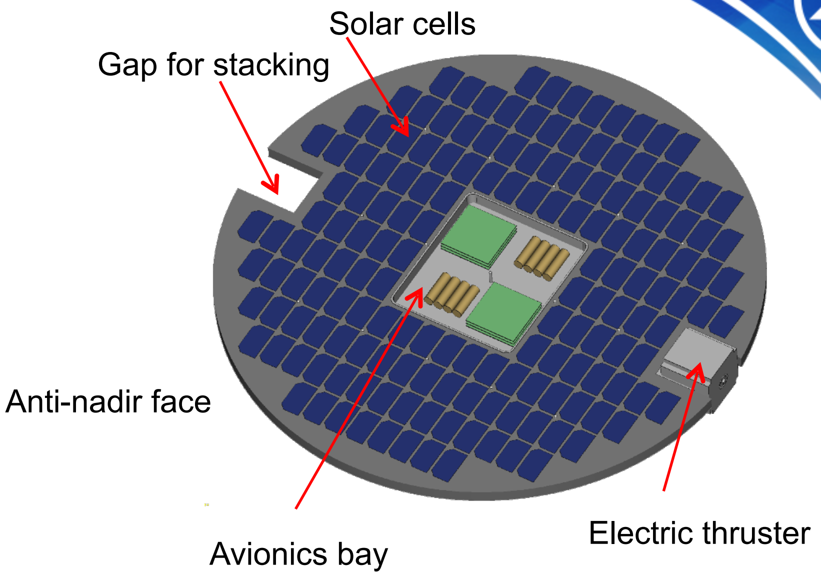
Data from M. Swartwout

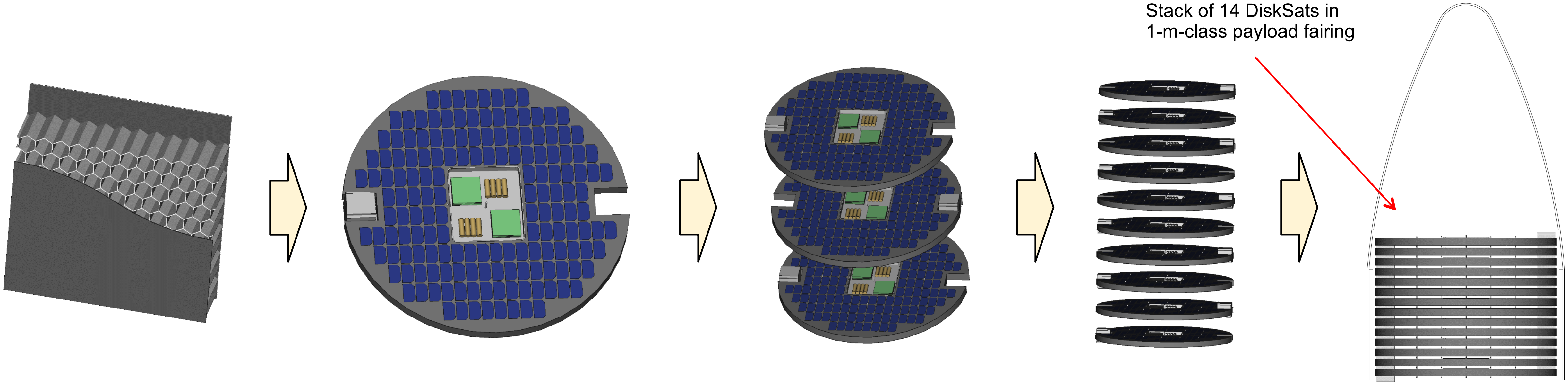
How to get the benefits of containerization without the limitations of CubeSats?

Out-of-the-(CubeSat)-Box

DiskSat – Containerization in an Alternate Form

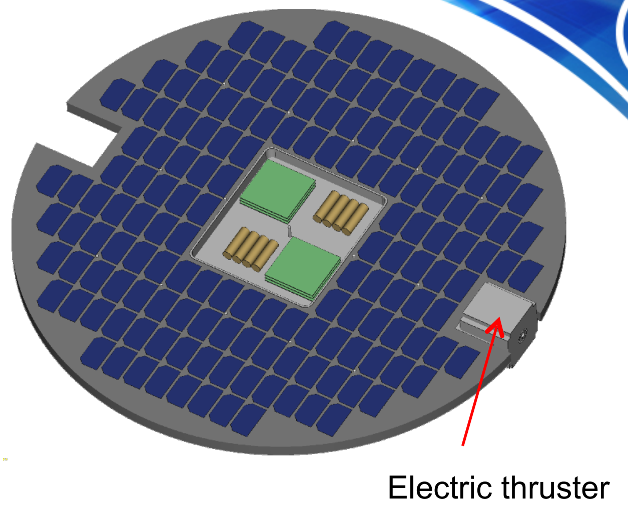
- Efficient shape: thin disk 1 meter diameter, 2.5 cm thick
  - *Large surface area for power and aperture* ***without deployables***
  - ***Volume equal to ~20U CubeSat***
- Stackable for containerization
  - *Sized to stack in 1-m-class payload fairing*
- Simple, low-mass construction
  - *Graphite/epoxy composite sandwich – mass < 3 kg/m²*
  - *Satellite components distributed throughout internal volume, or in a central avionics bay*



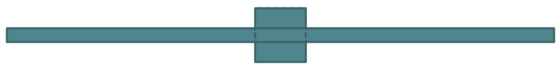


Maneuverability

- Orbit raising
  - *Initial deployment at lower altitude increases launch payload mass*
- Orbit maintenance
  - *Less than 10 m/s/year delta-v maintains 600 km orbit*
  - *VLEO: high delta-v combined with low drag of DiskSat enables sustained flight in 250 km orbit*
- Rapid rephasing of constellations
- Cis-Lunar space
  - *<4000 m/s delta-v required for transfer from GEO to lunar orbit*

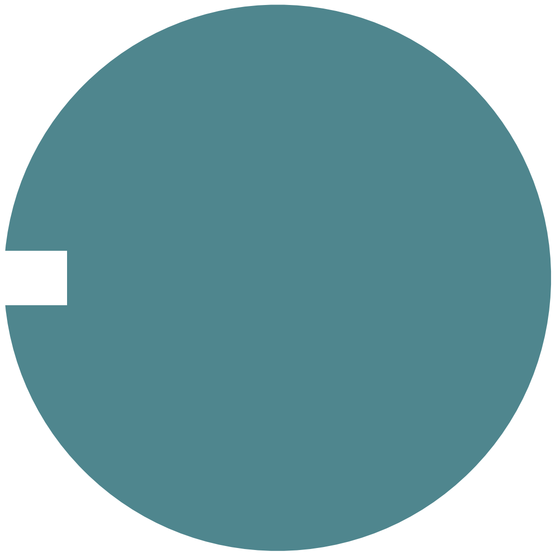


Low drag for VLEO operations



322 cm² cross section

High drag for rapid deorbit

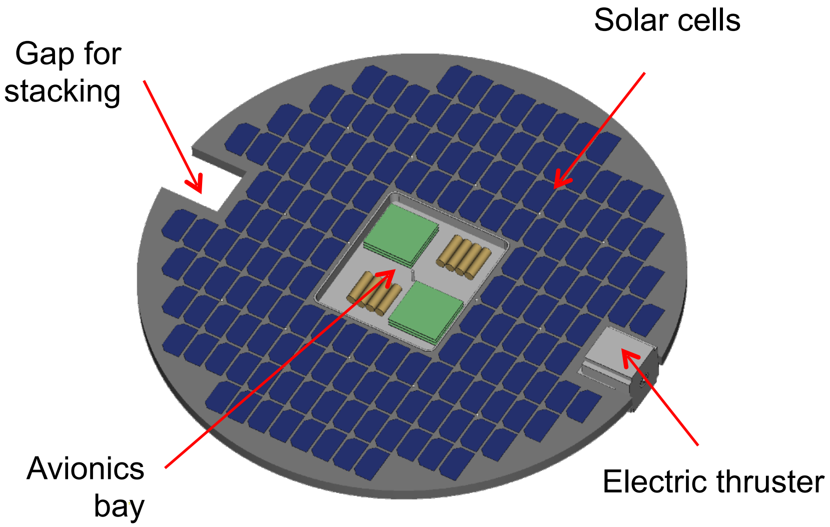


7700 cm² cross section

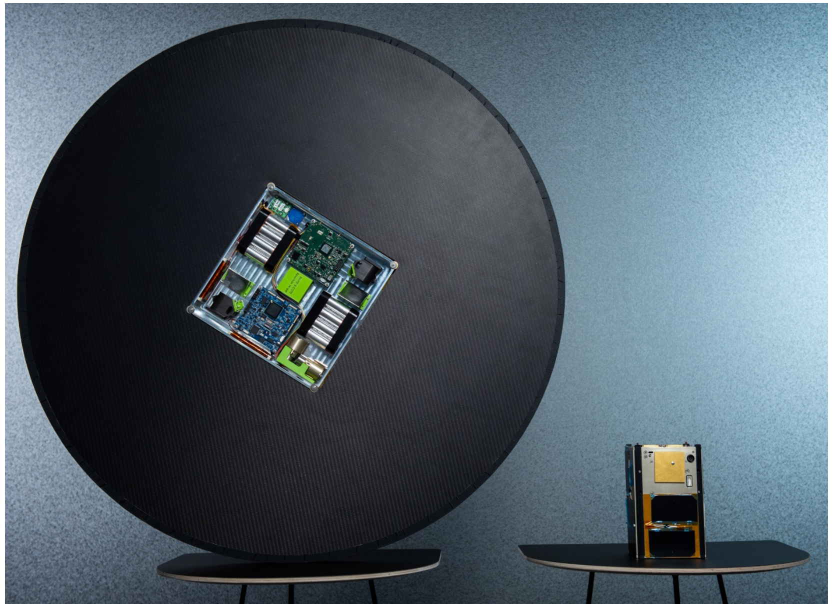
DiskSat has unparalleled orbit agility; high power combined with low drag and low mass

Demonstration Mission

First flight of DiskSat



Notional demonstration mission satellite with propulsion



Mockup of a 1-meter DiskSat next to a 1.5U CubeSat

Description:

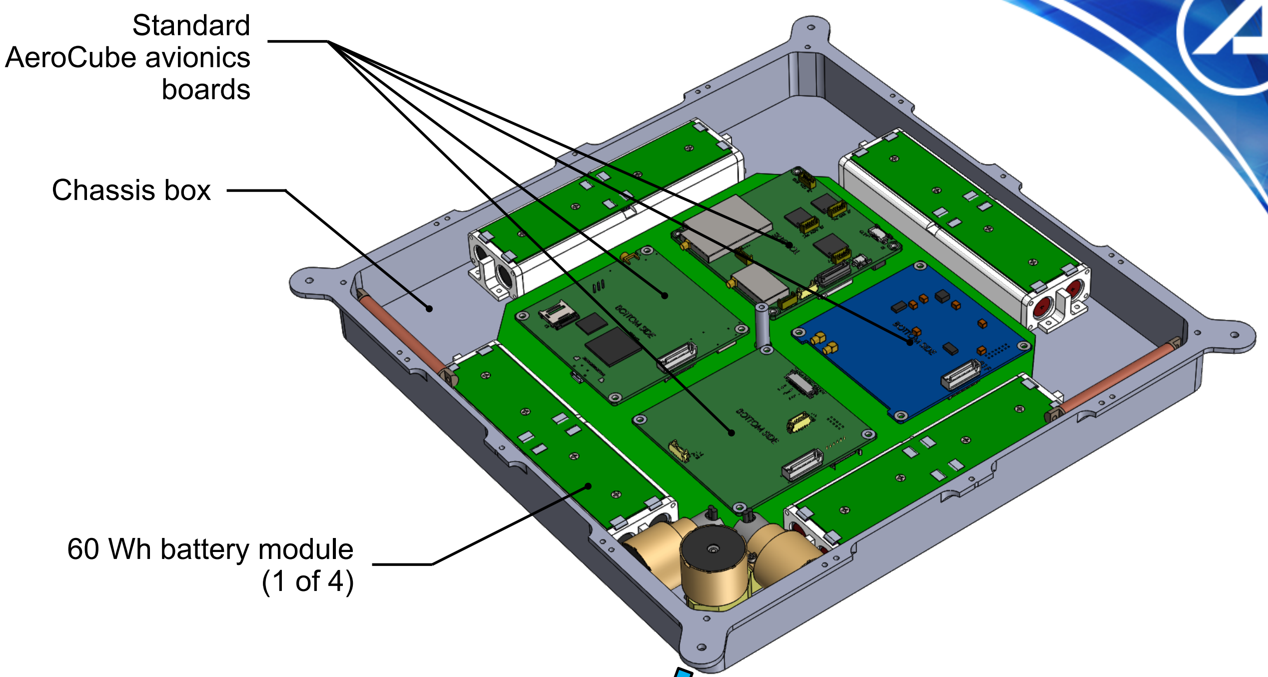
- Fly four first-of-their-kind "DiskSat" satellites at increasingly lower altitudes, equipped with electric propulsion
  - *DiskSat: 1 m diameter, 2-3 cm height*
  - *Fly in edge-on orientation for extremely low drag*
  - *Fly 2 vehicles in circular orbit at ≤250 km altitude*
  - *Fly another 2 vehicles in elliptical orbit with perigee <200 km*
- Two-dimensional form factor provides large surface area for ~200 W peak power in 10 kg package
- Experiment goals:
  - *Demonstrate performance/utility of DiskSat form factor*
  - *Demonstrate multi-satellite deployment with complementary Dispenser*
  - *Demonstrate generation of 200 W peak power*
  - *Demonstrate maneuverability and flight in VLEO*
- Status
  - *DiskSat structure/avionics conceptual design complete*
  - *DiskSat stack vibration testing started*
  - *Dispenser conceptual designs being evaluated*
- Maturity level:
  - *DiskSat: **medium maturity –** heritage avionics and subsystems flown on multiple previous missions, integration into disk form factor is new*
  - *Dispenser: **low maturity –** new development for containerization and deployment of DiskSats*

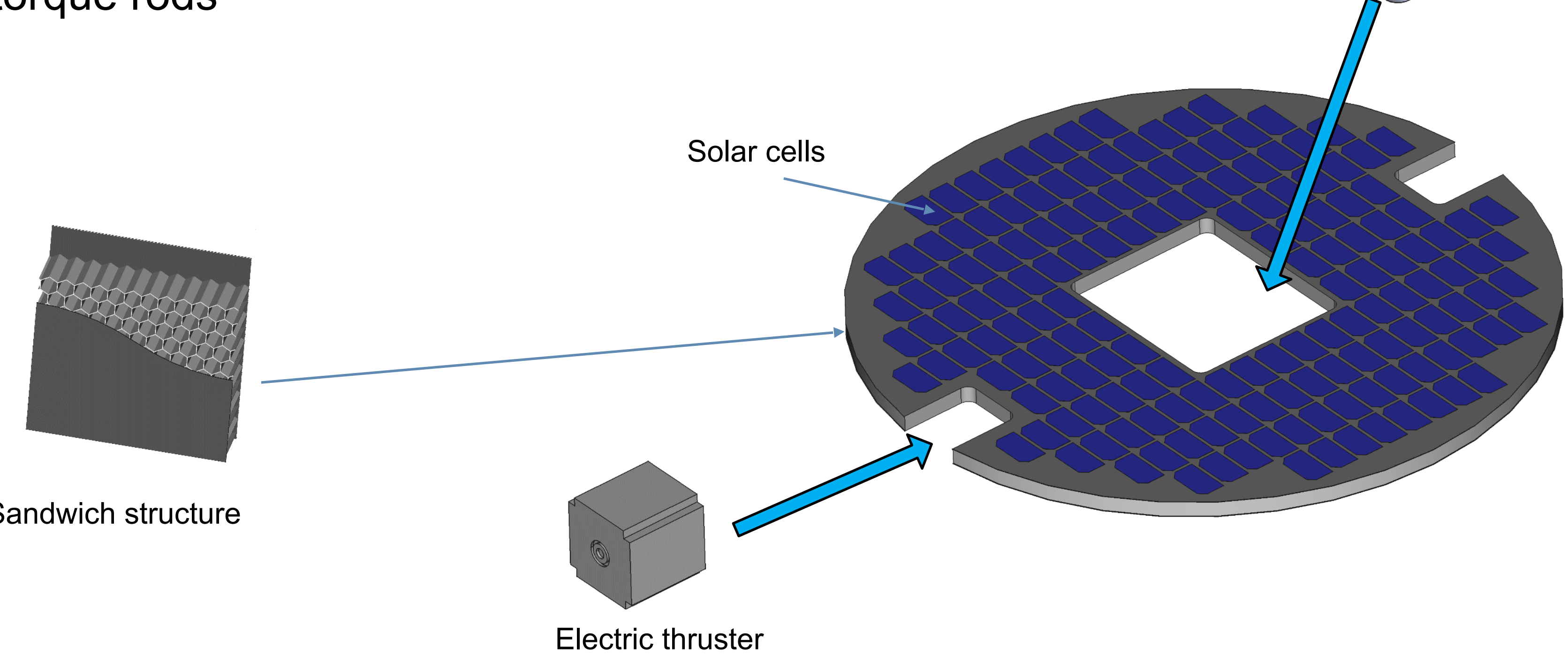
- First flight anticipated in FY 2024

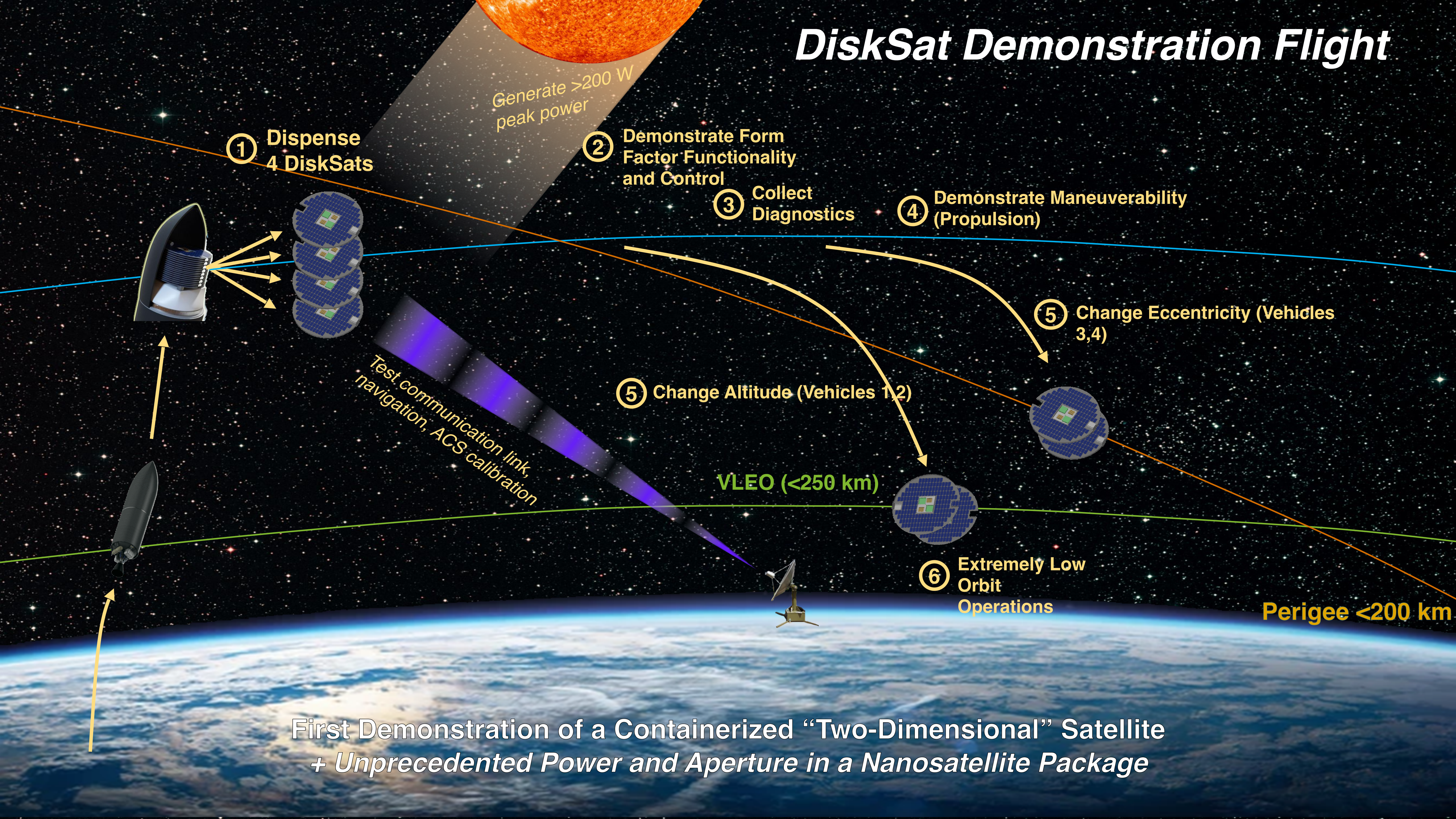
Mission Overview

Spacecraft

- Structure: composite sandwich with aluminum honeycomb core and graphite/epoxy face sheets
- Avionics in central chassis box derived from AeroCube avionics suite
- Electric propulsion
- Power: >150 W solar cells on one face
- Three-axis attitude control using reaction wheels and magnetic torque rods

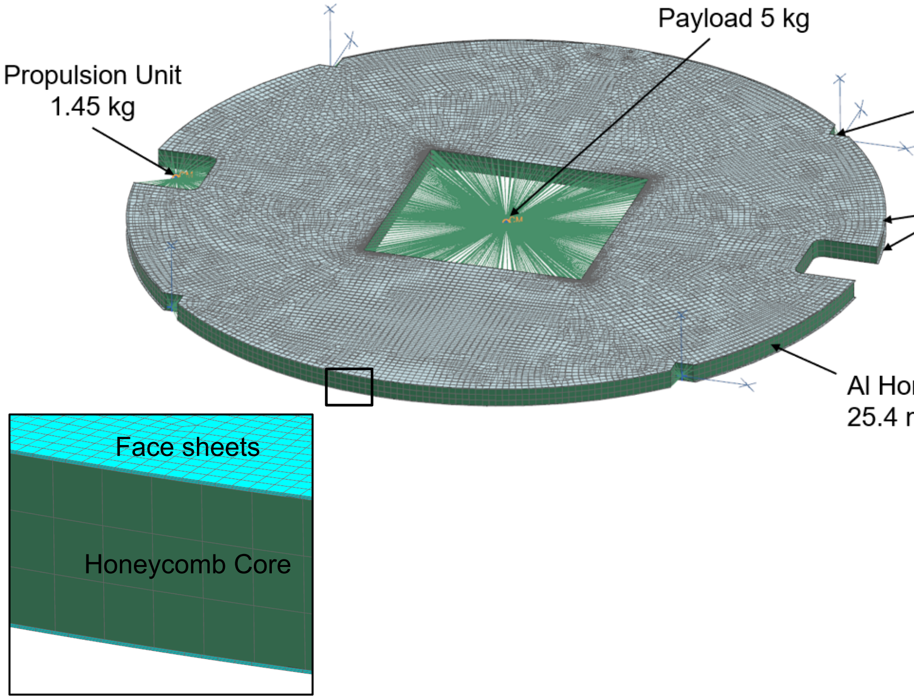




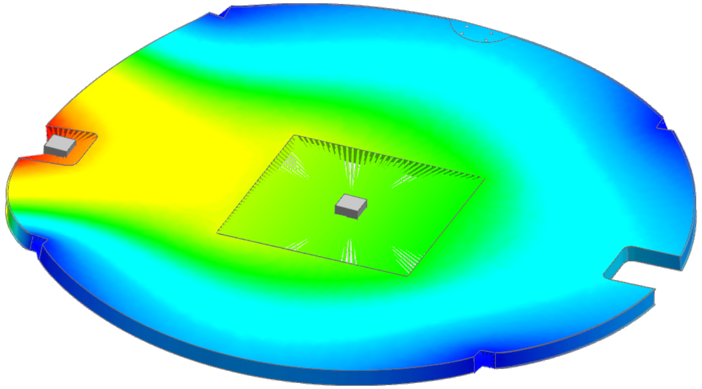

DiskSat Demonstration Flight
Generate >200 W peak power
1 Dispense 4 DiskSats
2 Demonstrate Form Factor Functionality and Control
3 Collect Diagnostics
4 Demonstrate Maneuverability (Propulsion)
5 Change Eccentricity (Vehicles 3,4)
5 Change Altitude (Vehicles 1,2)
Test communication link, navigation, ACS calibration
VLEO (<250 km)
6 Extremely Low Orbit Operations
Perigee <200 km
First Demonstration of a Containerized "Two-Dimensional" Satellite
+ Unprecedented Power and Aperture in a Nanosatellite Package

Structural Analysis

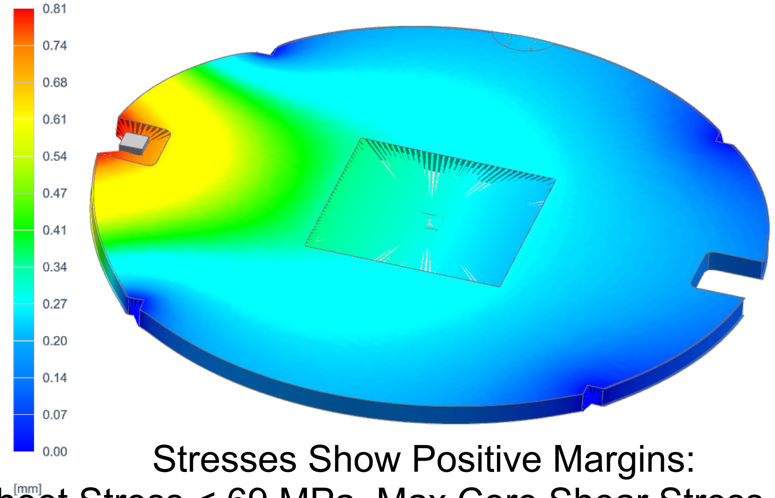
Trades on Materials, Thickness, Edge Support



1st Mode 121 Hz



Maximum deflection < 1 mm under 42.3g load



Stresses Show Positive Margins:
Face-sheet Stress < 69 MPa, Max Core Shear Stress ~ 0.69 MPa

Sandwich Panel Materials Can be "Tuned" to Control Stiffness

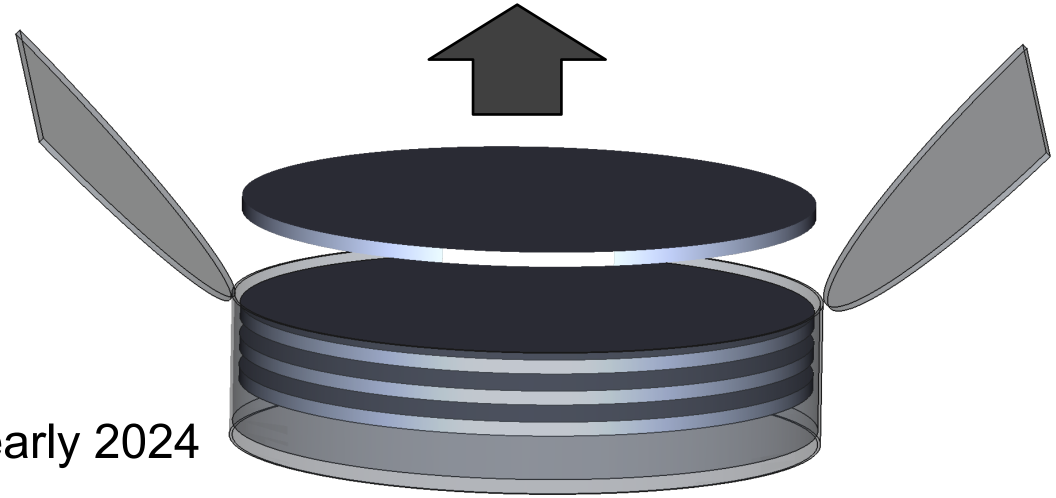
Main Parameters:

- Face-sheet Material: Carbon-Fiber vs. Aluminum
- Carbon-Fiber Modulus
- Face-sheet Thickness
- Honeycomb Density, Cell Size, Thickness

DiskSat is very stiff, can be supported along edges without internal support

Next Steps

- Dispenser development
  - *Eliminating the need for internal disk-to-disk support opened the trade space for DiskSat dispensing mechanisms*
  - *Alternatives being evaluated, preliminary designs under way*
  - *Detailed design and testing in FY 23*
  - *Flight hardware delivery in late 2023*
- DiskSat development
  - *Detailed design and build*
  - *Four flight units ready in late 2023*
- Launch through Space Test Program, aiming for late 2023 or early 2024
- Development and publication of a DiskSat standard
- Facilitating future shared DiskSat flights



DiskSat Standard

Modeled on CubeSat Standard

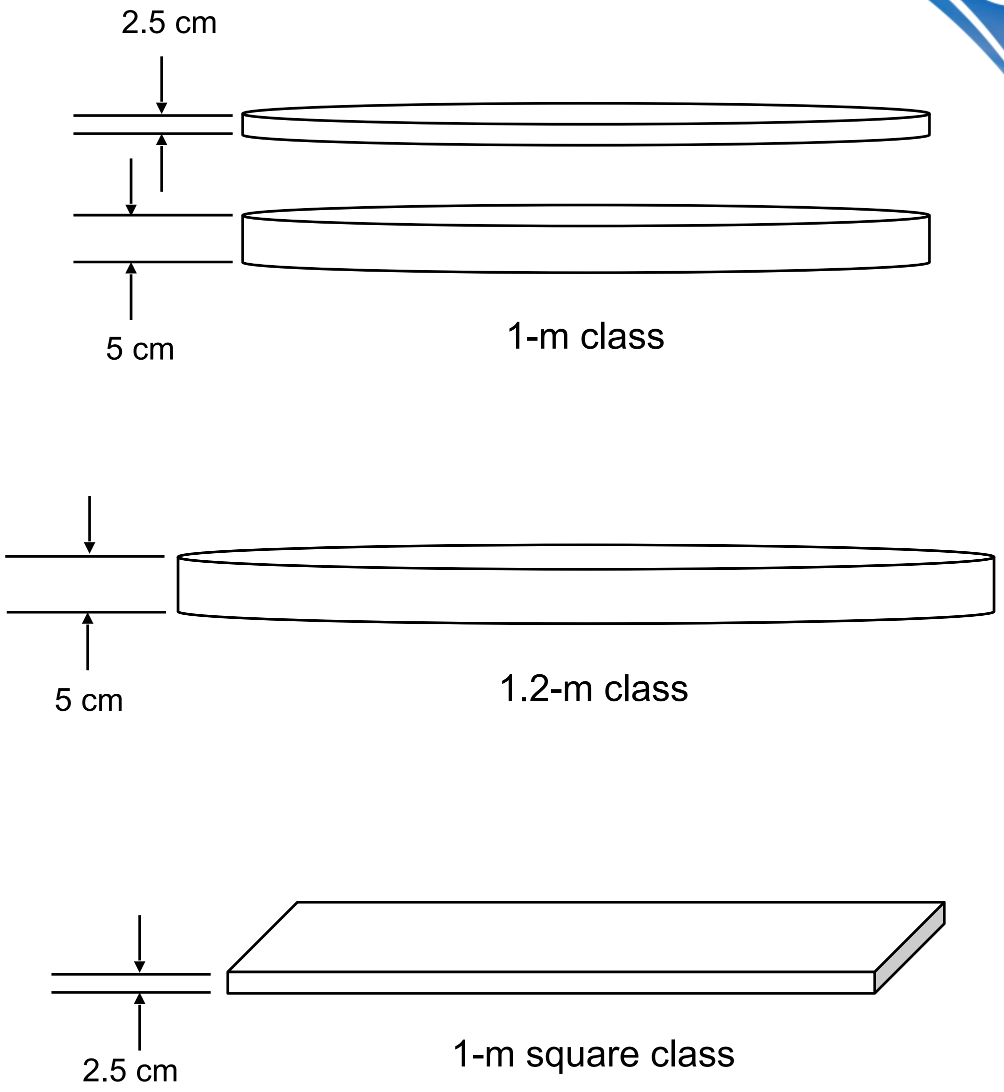
- Goals
  - *Standard interface with launch vehicle (containerization)*
  - *Safety of flight (rideshare)*
- Interface definition will incorporate dimensions and loads, but will not necessarily specify materials
- Safety of flight requirements will parallel CubeSat standard
  - *Electrical system powered off until after satellite deployment*
  - *Battery protection*
  - *Hazardous materials limits*
  - *Testing requirements*
  - *Deployable components (solar panels, antennas, etc.) constrained until after satellite deployment*

- Dispenser interface design goals
  - *Simplicity*
  - *Reliability*
  - *Commonality across DiskSat classes*

DiskSat Standard

Degrees of Freedom

- DiskSat classes
  - *Based on diameter or other lateral dimensions*
  - *Sized to make maximum use of available launch volume*
- Multiple DiskSats of the same class can be stacked together for launch
- Each class will have class-specific constraints
  - *Lateral dimensions (and tolerances)*
  - *Minimum thickness (required for dispenser interface)*
  - *Location and design of dispenser interfaces*
  - *Maximum mass per unit thickness*
  - *Center of mass offset limit*
  - *Maximum deflection under launch loads*
- Initial classes:
  - *1-m circular (demonstration flight)*
  - *1.2-m circular*
- Additional classes to be defined as needed



Summary

Containerization outside the CubeSat box

- Aerospace is developing a new paradigm for satellite form factor: DiskSat
  - *"Two-dimensional" bus architecture is low SWaP and has large aperture without deployables*
- Form factor offers unique capabilities in a 10–20 kg package:
  - *Large surface area for high power and RF apertures*
  - *Large total volume for accommodating payloads*
  - *Large ΔV via electric propulsion for maneuvering, altitude changes, or even cis-lunar missions*
    - Enables very-low-altitude operations (<250 km) via low-drag edge-on flight
- Diverse mission applications:
  - *Large constellations*
  - *RF receivers and transmitters*
  - *Radar*
  - *High power*
- Demonstration mission under development
  - *Fours satellites and dispenser scheduled for delivery in late 2023, flight in 2024*
- DiskSat standard being prepared
  - *Modeled on CubeSat standard*
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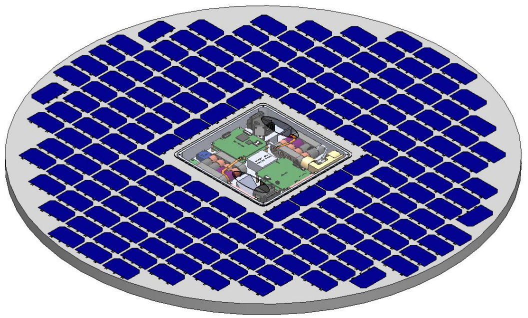

100 cm dia (166 W installed)

Aerospace is soliciting input from potential launch providers and users on defining the DiskSat standard

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