Gossamer Orbit Lowering Device (GOLD) for Safe and Efficient CubeSat Deorbit

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Topics

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- GOLD CubeSat Applications and Demo Flight
- GOLD Design and Development Status
- Example CubeSat System Performance
- Comparison of De-orbit Methods and their Risks
- Summary

GOLD System Overview

GOLD† Overview

- ***Applications:*** **de-orbit of CubeSats, defunct satellites, and spent launch vehicle stages; debris mitigation**
- ***Orbits:*** **LEO to about 1,500 km altitude**
- ***Concept:*** **Increases cross-section area by inflation-maintained ultra-thin envelope which accelerates natural atmospheric drag decay from centuries to months**
- ***System:*** **UV and AO protected envelope, inflation control and pressure maintenance, controller, sensors & power**
- ***CONOPS:*** **1) attached to satellites or upper stages before launch, 2) delivered to derelict satellites by orbital tenders, or 3) targeted & controlled reentry of large space platforms**
- ***Risk:*** **Lower probability of destroying operating satellites and creating new debris than bare spacecraft or other de-orbit methods**

† - Patent US 6,830,222 issued December 14, 2004

GOLD CubeSat Applications and Demo Flight

CubeSat Deorbit

- **Satellites are required to meet the *25-year rule*: limitation in the maximum orbital lifetime for orbiting spacecraft proposed in 2002 by the IADC**
  - **Despite debris mitigation policies, space junk is a growing environmental concern**
- **Number of CubeSats in Earth orbit will increase significantly in near future**
  - **Growing use of CubeSats for education, tech demonstrations, or commercial use.**
- **On an Operational CubeSat, a 2-m diameter GOLD envelope, including inflation system, would only require a ~2 in (~5 cm) cube and would weigh < 3 oz. (~85 g). Can use 3-9 μm thick Mylar or aluminized Kapton**

CubeSat GOLD Demo Flight

- GAC is planning a GOLD CubeSat demo flight.
- GAC is looking for CubeSat developers to partner with.
- 3U CubeSat: 2U for GOLD and solar panels, and 1U for CubeSat bus
- Demo envelope material: Linear Low-Density Polyethylene (LLDP)
- Expecting to use CubeSat resources instead of independent power system

CubeSat Deployed GOLD System

GOLD Design and Development Status

Operational System Components

- **Essential components:**
  - **Ultra-thin and lightweight inflated envelope**
  - **Envelope storage container**
  - **Inflation and pressure maintenance system**
- **Additional components depending on requirements:**
  - **Gas reservoir**
  - **Sensors**
  - **Controller**
  - **Satellite interfaces**
  - **Power**

Technical Analysis Completed

- State of envelope near entry conditions
- Effects of solar activity on performance
- Effects of space environments (AO†, UV, solar pressure, gravity gradient and aerodynamic forces, thermal, etc.)
- Orbital debris and meteoroid environment
- Envelope holing and leakage
- System dynamical analysis during deployment and operations

† - Atomic oxygen

System Design Studies Completed

- System requirements and functional block diagram
- Mass, volume and power breakdown with contingencies
- Film and coating material research, trade studies and availability
- Envelope design, packaging and deployment
- Inflation gas and its storage options
- Preliminary system and subsystem design
- Sensor requirements and analysis
- Cost estimates

Example System and its Performance

Operational Range

Compliance with the 25-year rule normally restricts satellite deployments to altitudes of about 600 km or less, but with the use of GOLD a CubeSat can comply with the 25-year rule at much higher altitudes

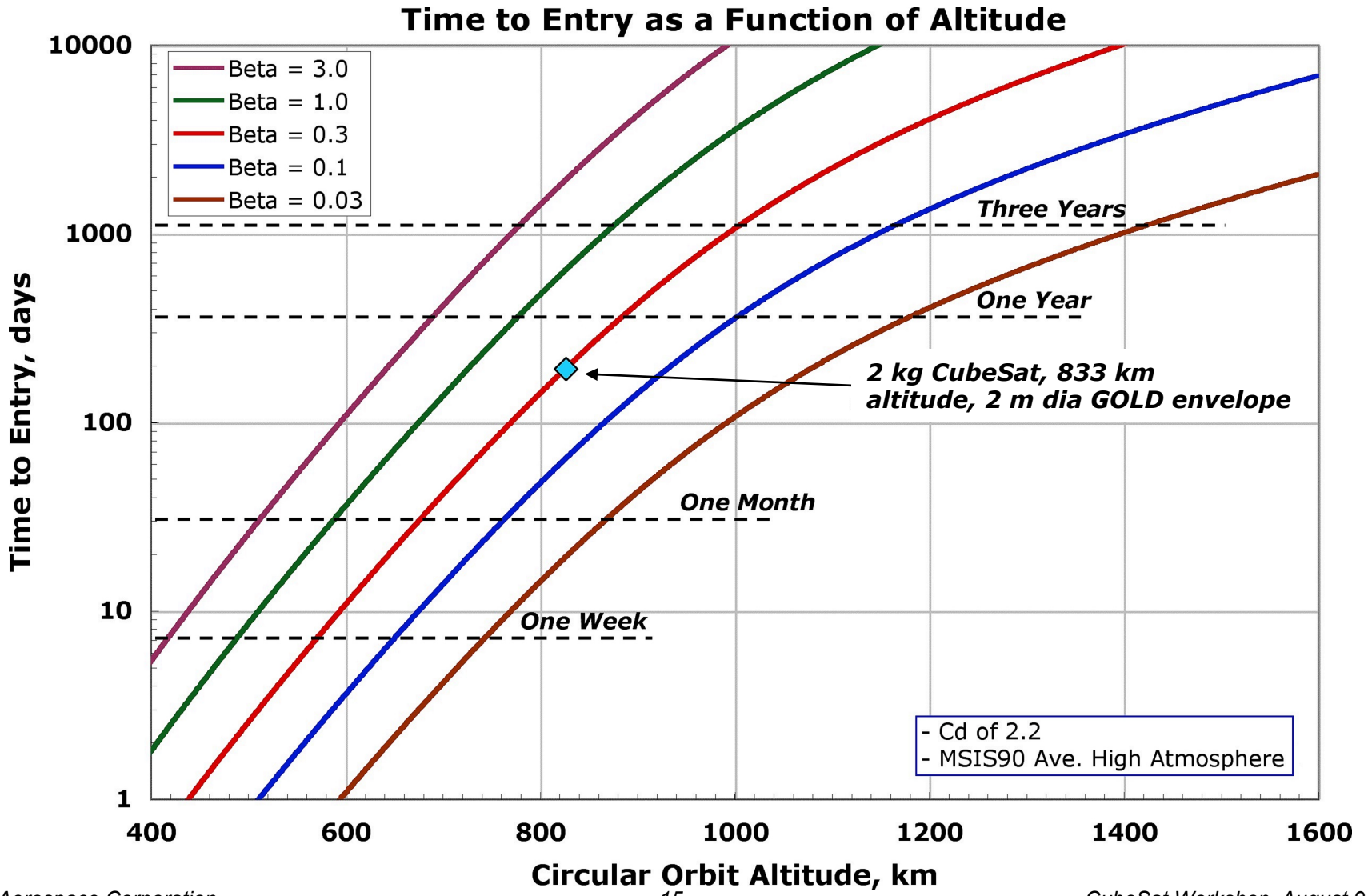
Sample Results Using NASA's Debris Assessment Software (DAS)

	CubeSat without GOLD		CubeSat GOLD Demo		CubeSat GOLD Operational	
CubeSat Size	1U		3U		1U	
CubeSat Mass	Approx. 1 kg		Approx. 2 kg		Approx. 1 kg	
Area/Mass Ratio	0.01 m²/kg		1.57 m²/kg		3.14 m²/kg	
Ballistic Coefficient	45.45 kg/m²		0.2894 kg/m²		0.1447 kg/m²	
Solar Conditions	Solar Min	Solar Max	Solar Min	Solar Max	Solar Min	Solar Max
Max Altitude for < 25 Year Decay Time	630 km	645 km	1165 km	1200 km	1330 km	1360 km
Max Altitude for < 1 Year Decay Time	365 km	475 km	585 km	880 Km	700 km	975 km
Decay Time from 833 km Altitude	> 100 years	> 100 years	3.67 years	0.68 years	3.14 years	0.33 years

Assumptions: c_D (Drag Coefficient)=2.2; Solar Min is around 2018 and Solar Max is around 2023; Orbital Inclination=45 deg (results are not very sensitive to inclination)

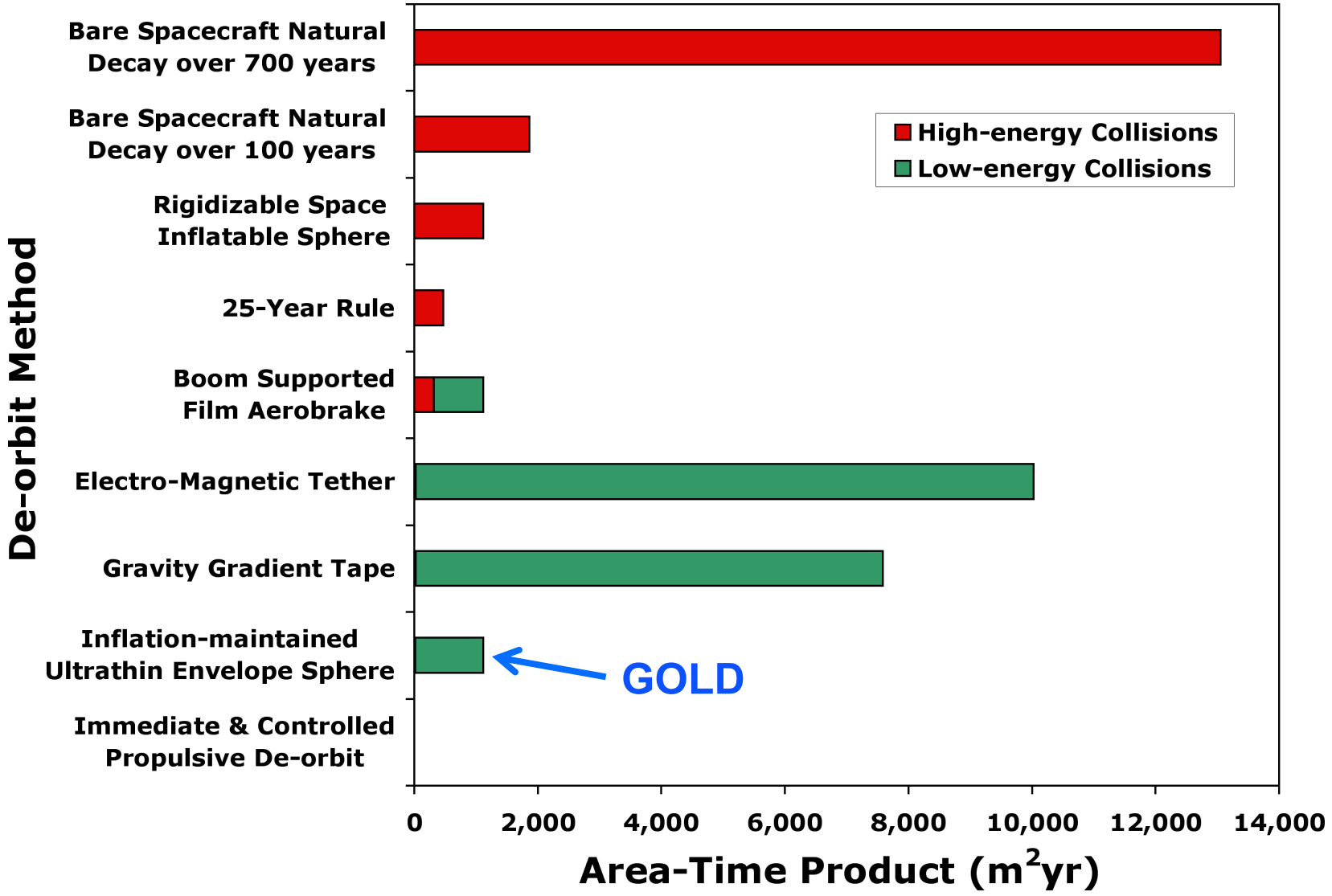
For an altitude of 833 km, a CubeSat using GOLD could reenter in about 8-12 months at solar mean conditions and in about 4 months at solar max conditions.

Decay Time vs. Altitude



Comparison of De-orbit Methods and Their Risks

Area-Time Product Summary



Comparison of De-orbit Methods

Method / Attribute	GOLD	Electro-magnetic Tether	Boom-supported Aerobrake	Gravity-gradient Tape	Rigidizable Space Inflatable	PROPULSIVE
Risk of Large Debris Object Generation	Low	Low	Medium	Low	Highest	Lowest
Risk of Disabling Other Satellites	Low	Highest‡	Low	High	Low	Lowest
Variable De-Orbit Rate	Yes	Yes	No	No	No	Yes
Targeted Reentry	Yes	No	No	No	No	Yes
Works with Tumbling Derelict Satellites	Yes	No	Yes	No	Yes	No
Works Equally Well for Any Orbit Inclination	Yes	No	Yes	Yes	Yes	Yes
Works for Any Spacecraft Attitude	Yes	No	No¥	No	Yes†	No
Works for Any Orbit Altitude	No	No	No	No	No	Yes
Relative Mass	Low	Low	Low	Low	High	High
Cost to Add to Satellite	Low/Medium	Low/Medium	Low	Low	Low	Highest

Legend:

¥ - Above a certain altitude, gravity gradient and solar pressure forces dominate drag forces, † - Only if near spherical

‡ - Without avoidance manuevers by either spacecraft.

GOLD Summary

- GAC is planning a GOLD CubeSat demo flight
- GAC is looking for CubeSat developers to partner with
- 3U CubeSat: 2U for GOLD system and solar panels, and 1U for CubeSat
- Increase atmospheric drag area of satellite using an ultra lightweight, inflation-maintained envelope
- Effective for space objects up to about 1,500 km altitude depending on object mass and solar activity
- Relatively mature design. Vacuum chamber tests and a flight demo are needed
- Low probability of destroying operating satellites and of creating new, dangerous debris
- Does not require a cooperative satellite to work
- Is highly scalable – CubeSats to large space platforms
- Satellite/stage integration and cost are also scalable