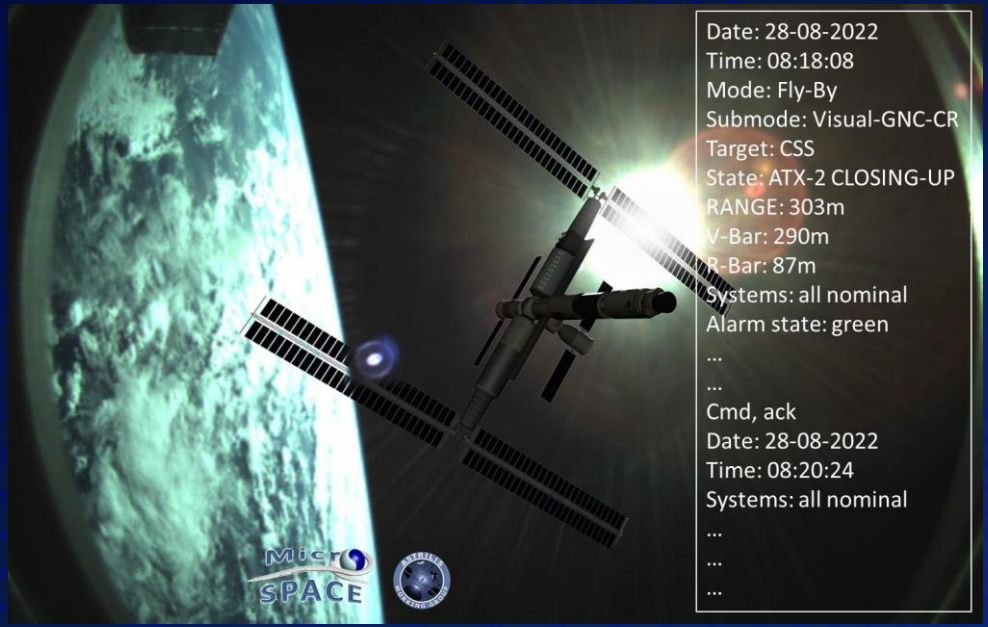
ASTRILIS REMOTE ASTEROID ACQUISITION MISSION, THE MOST EFFICIENT SOURCING OF MATERIALS FROM SPACE FOR HUMANKIND

www.astrilis.org www.micro-space.org

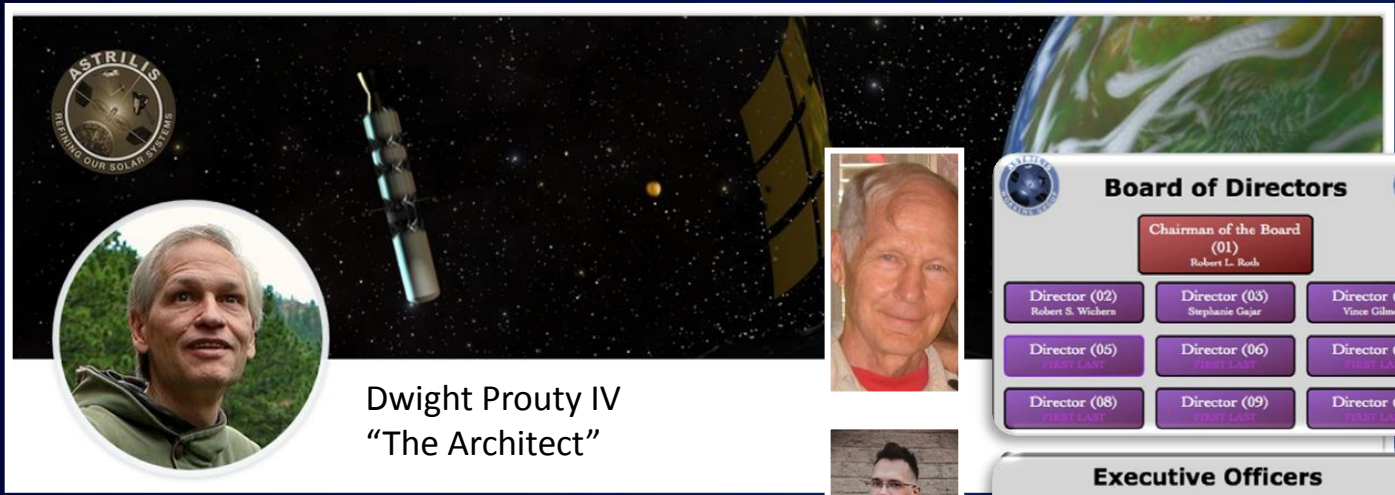
UN/CSS cooperative initiative: Astrilis RAA is one of the 42 projects submitted

1. Redirect asteroids that are capable of impacting Earth;
2. Park asteroids in GSO for PEACEFUL use and development of our solar system



TEAM ASTRILIS

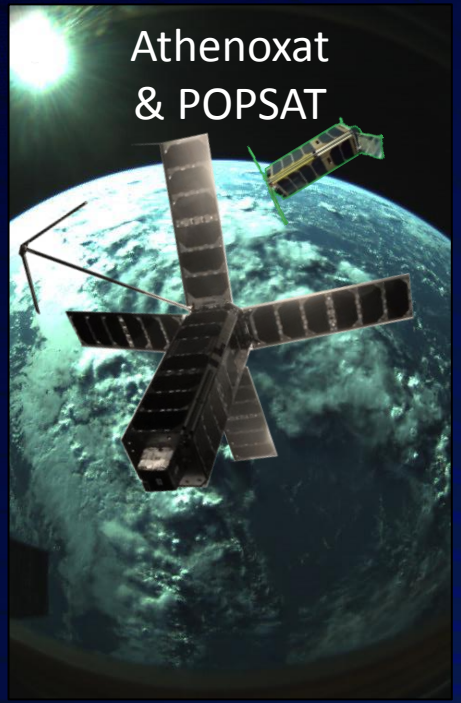
www.astrilis.org

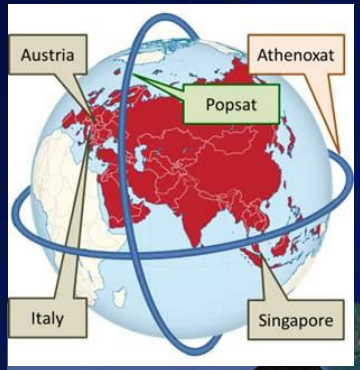


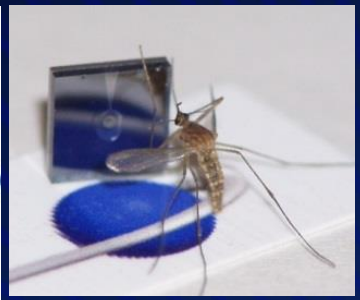
Dwight Prouty IV
“The Architect”

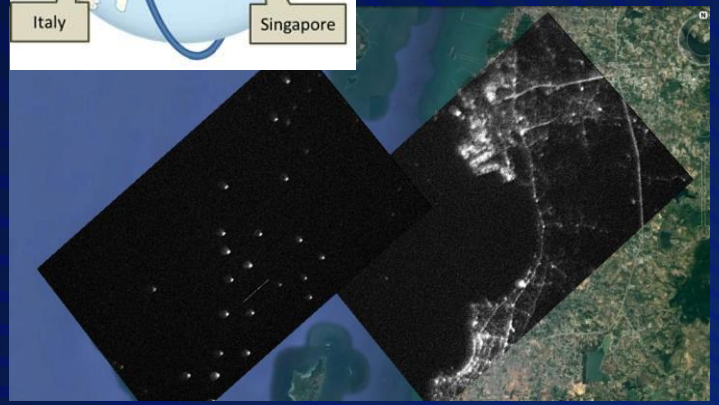
TEAM MicroSpace

www.micro-space.org









UNITED NATIONS
Office for Outer Space Affairs

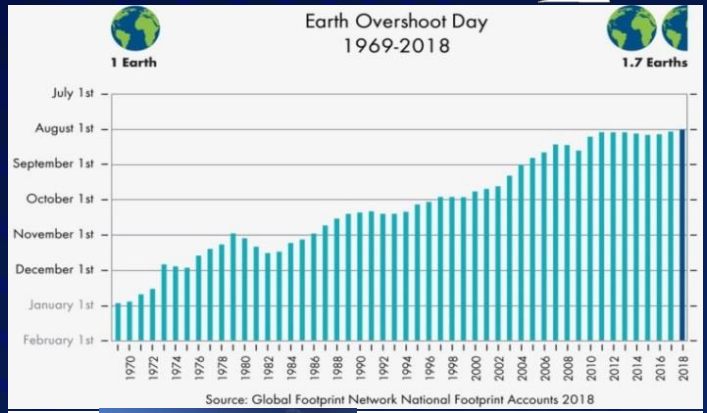
Our Principles

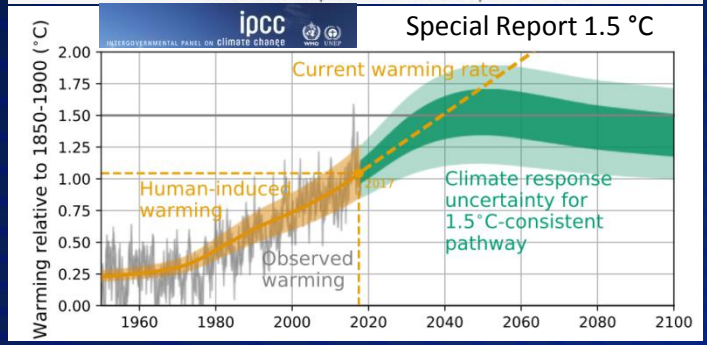
Physics Laws,
Facts, no fantasies,
no Arbitrary Assumptions

- Necessary:
  - Human expansion
  - Respect for the environment
  - Equality and fairness between all human beings
- Feasible

PROBLEM
Earth is a closed system

https://oeru.org/oeru-partners/otago-polytechnic/

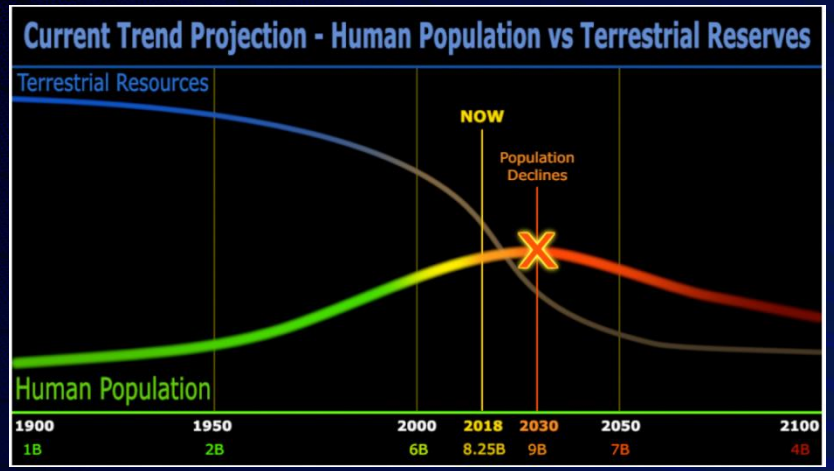


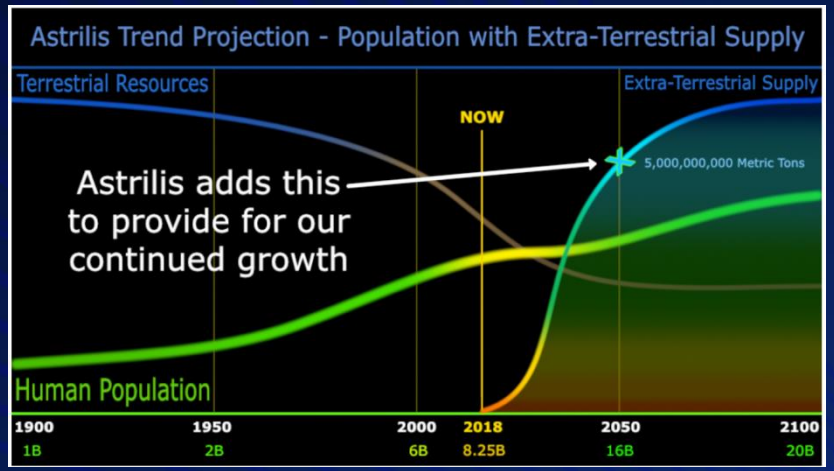


PROBLEM
Size < Constraint

CLOSED = LIMITED → DECLINE

OPEN = UN-LIMITED → GROWTH

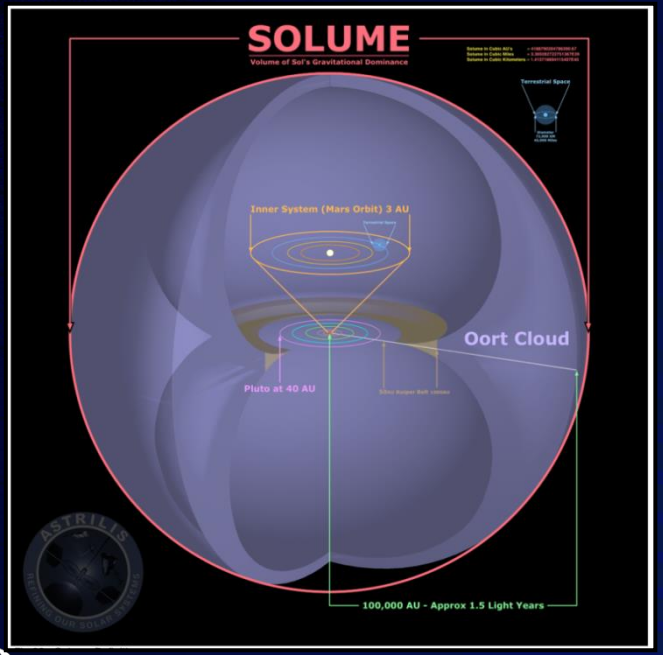


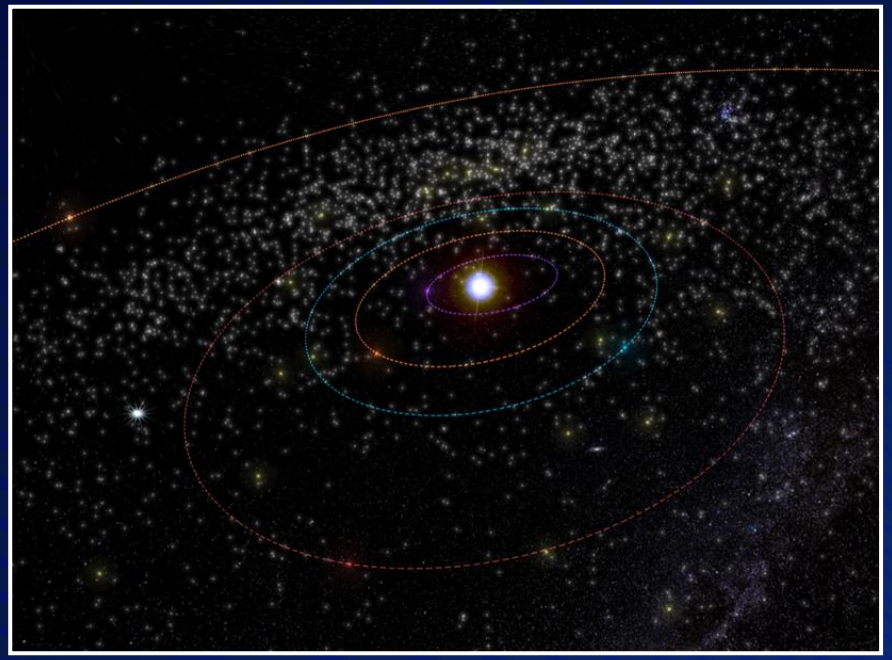


20,000 x  = 5 Billion (metric) tons / year

UNITED NATIONS
Office for Outer Space Affairs

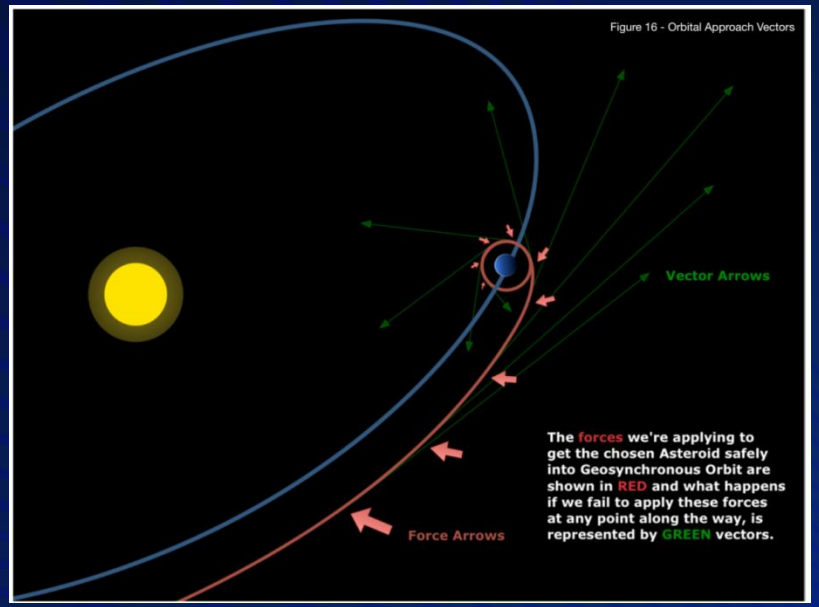
SOLUTION, WHAT
Open to the “Solume”



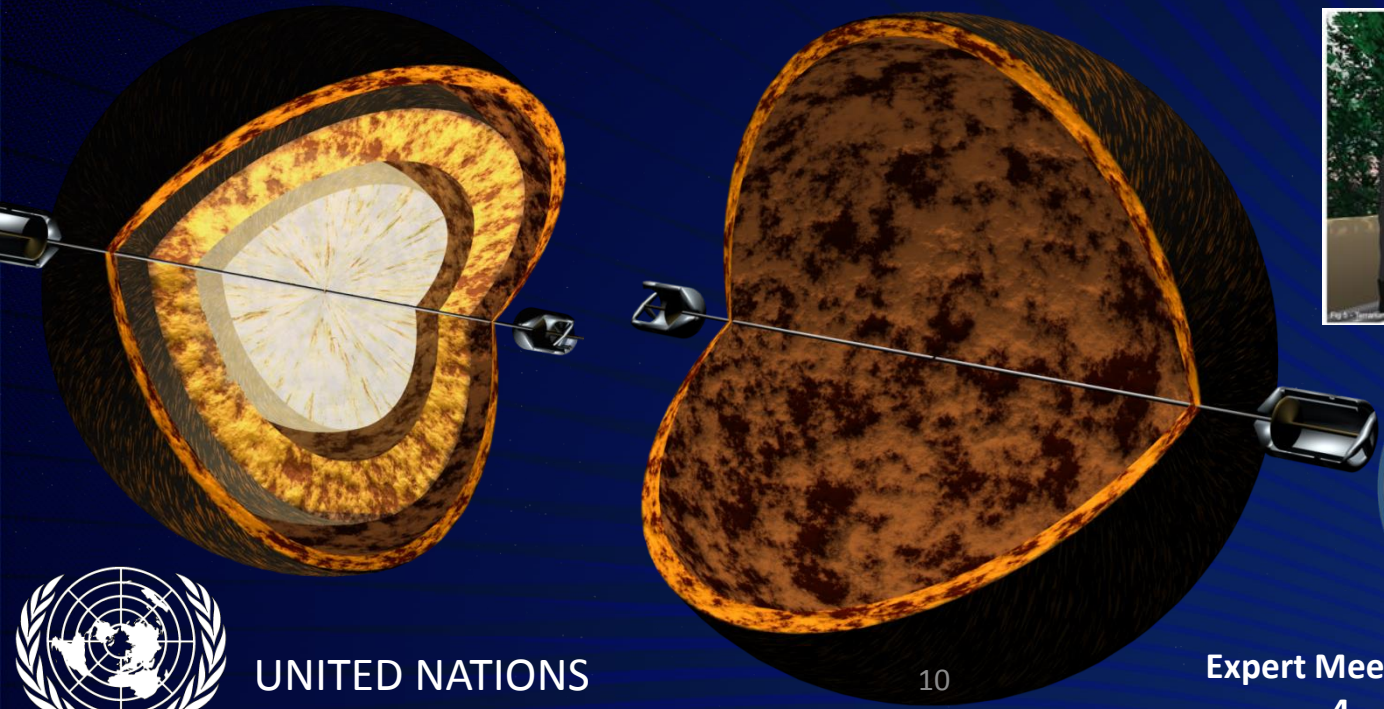


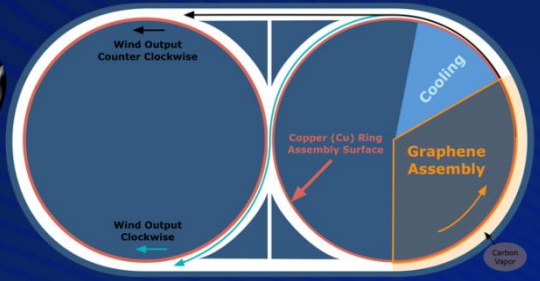
SOLUTION, WHAT
Asteroid Acquisition and Parking in to GSO

For example:
162173 Ryugu
Size: 1km
Mass: 4.5×10^8 ton
We need 10/year…



SOLUTION, WHAT
Asteroid Re-Purposing for Habitat and Industry

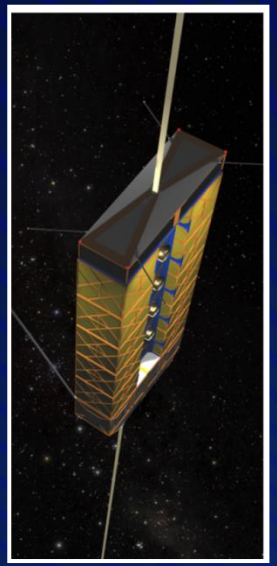




UNITED NATIONS
Office for Outer Space Affairs

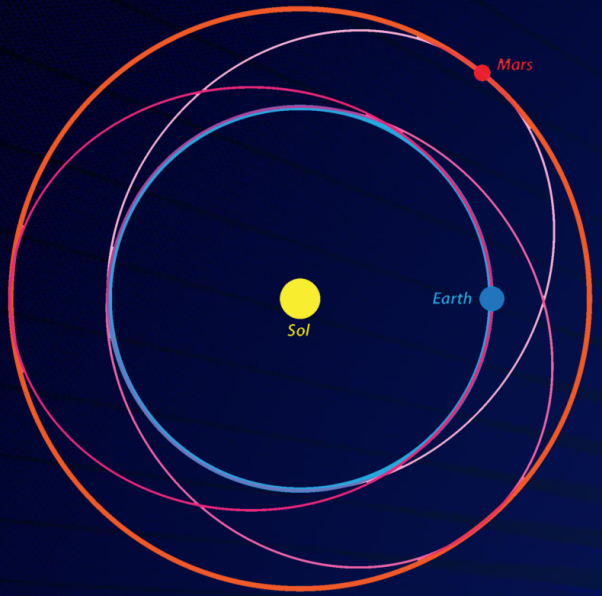
Expert Meeting on Human Space Technology
4 – 6 December, VIC, Vienna, Austria

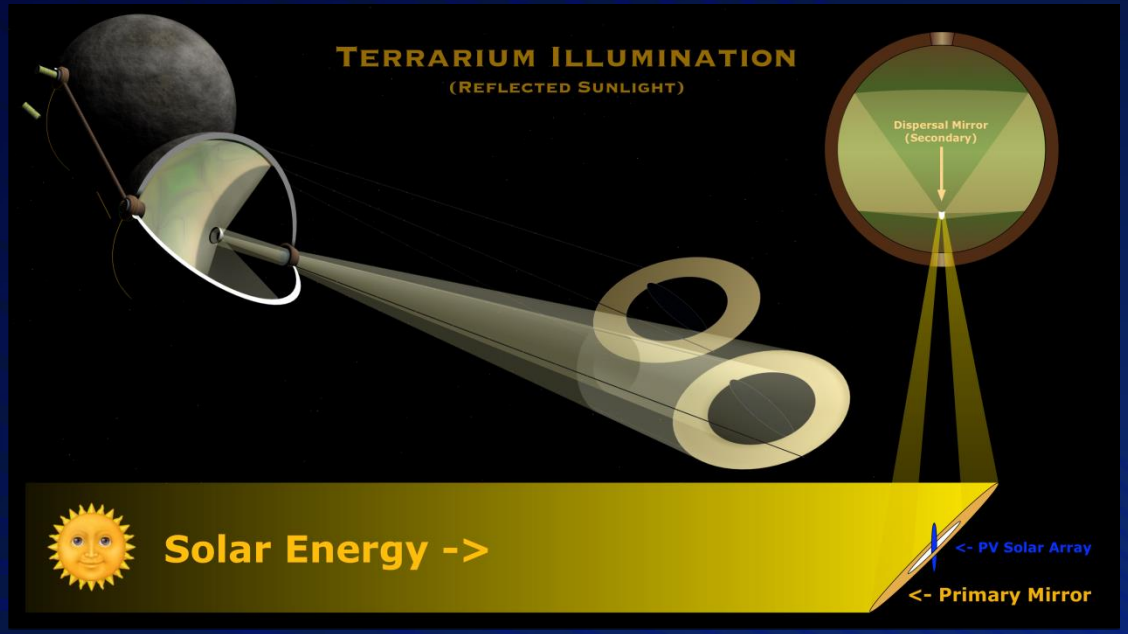
SOLUTION, WHAT
Space Elevator



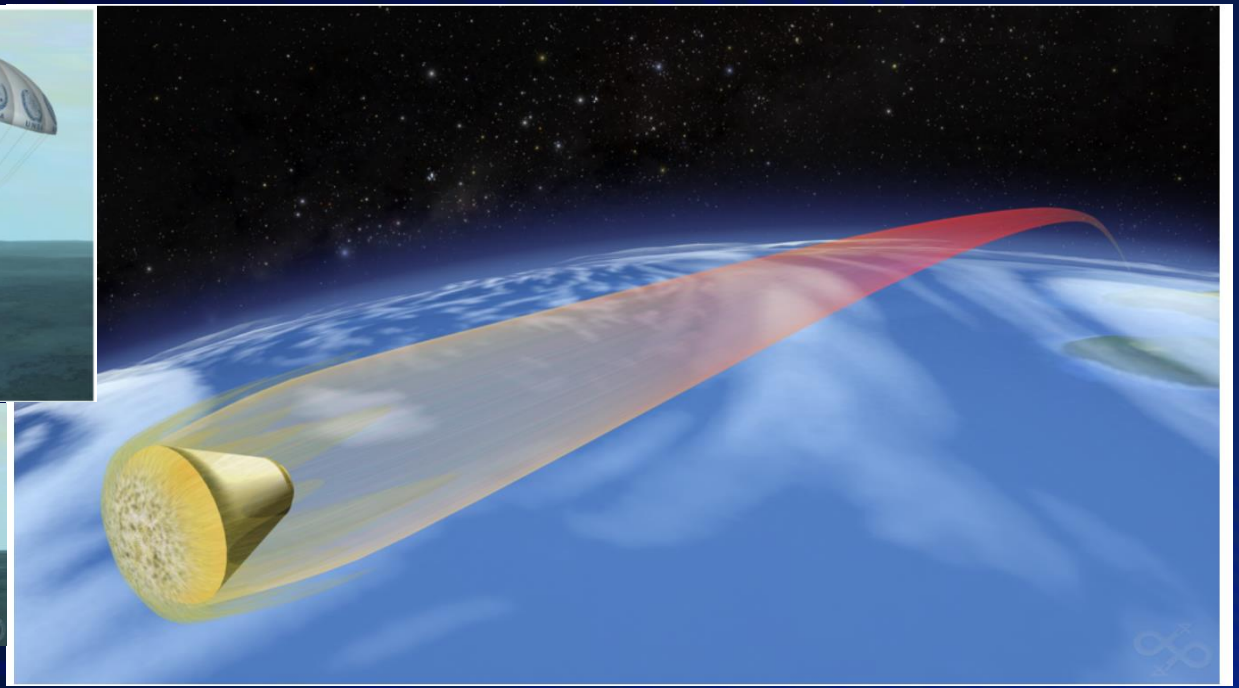
"The Space Elevator will be built about 50 years after everyone stops laughing."
[by Arthur Kantrowitz according to Arthur C. Clarke,
http://spaceref.com/space-elevator/the-space-elevator-thought-experiment-or-key-to-the-universe-by-sir-arthur-c-clarke.html]

SOLUTION, WHAT
Earth-Mars Transfers



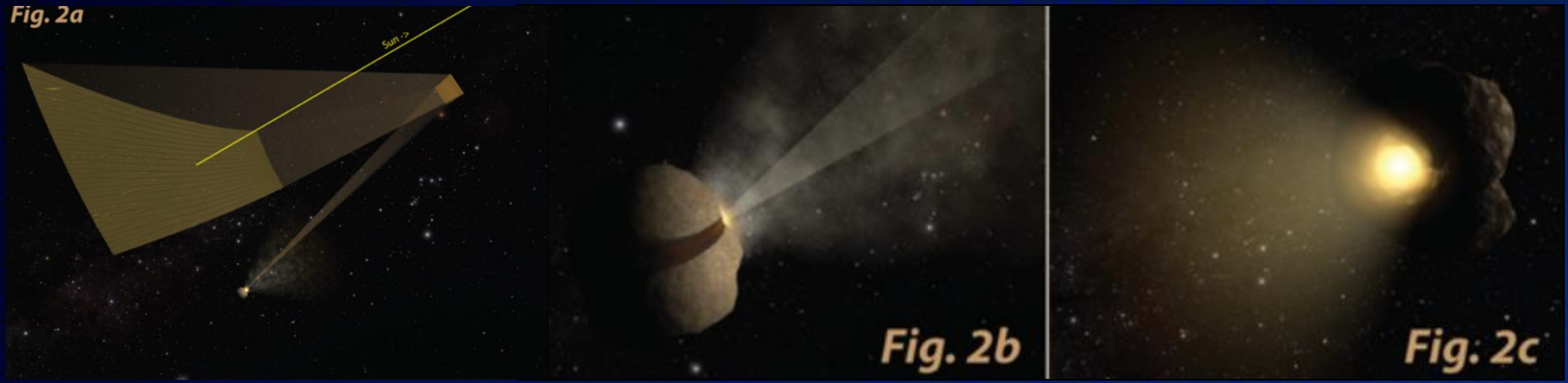


SOLUTION, WHAT
Return On Investment

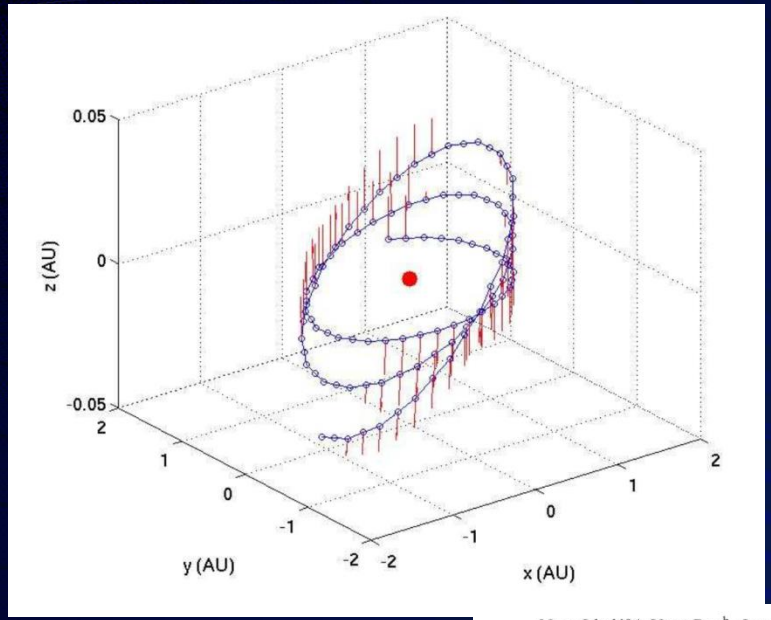


SOLUTION, HOW
Redirection by Vaporizing

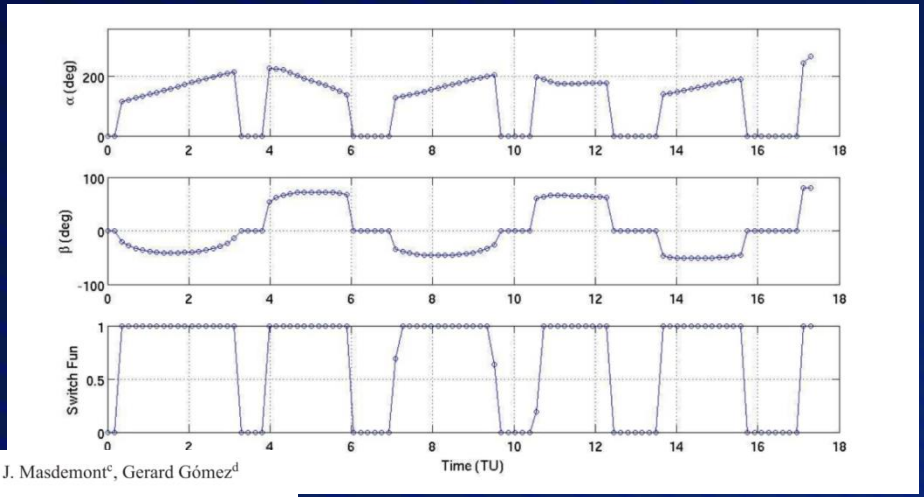
Minimal use of propellant,
Return trip fueled by the Sun !



SOLUTION, HOW
Necessary Thrust



Asteroid 2011MD (200 ton class)
Thrust = 15N ON/OFF profile → 985 days to L2



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[b]Department of Earth and Space Science and Engineering, York University, Canada
[c]IEEC & Departament de Matemàtica Aplicada I, Universitat Politècnica de Catalunya, Spain
[d]IEEC & Departament de Matemàtica Aplicada i Anàlisi, Universitat de Barcelona, Spain

SOLUTION, HOW
Necessary Thrust

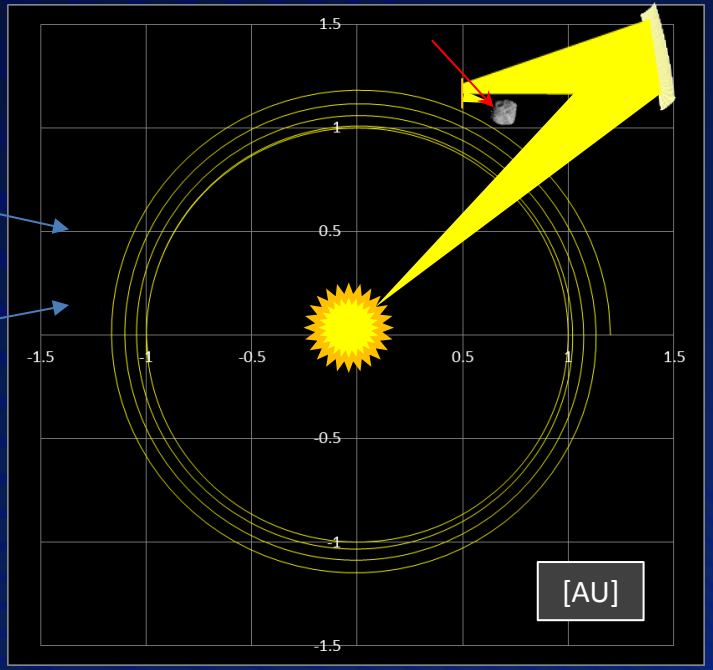
Spiral Transfer to Earth							
Gravitational Parameter (Sun)	mu	m3/s2	1.327E+20				
Astronomical Unit	AU	m	1.496E+11				
Initial radius	DeltaAU		0.1	0.2	0.4	0.8	1.6
		m	1.65E+11	1.80E+11	2.09E+11	2.69E+11	3.89E+11
	r0/r		1.1	1.2	1.4	1.8	2.6
Initial velocity	v0	m/s	28397	27188	25171	22199	18471
		km/s	28.4	27.2	25.2	22.2	18.5
required acceleration		m/s2					
time to transfer							
years	s						
2	63072000		-2.2E-05	-4.1E-05	-7.3E-05	-1.2E-04	-1.8E-04
4	1.26E+08		-1.1E-05	-2.1E-05	-3.7E-05	-6.0E-05	-9.0E-05
8	2.52E+08		-5.5E-06	-1.0E-05	-1.8E-05	-3.0E-05	-4.5E-05
asteroid mass	Mast	kg	1.00E+09				
		Mton	1				
required force		kN					
years	s						
2	63072000		-22.0	-41.1	-73.1	-120.2	-179.4
4	1.26E+08		-11.0	-20.6	-36.6	-60.1	-89.7
8	2.52E+08		-5.5	-10.3	-18.3	-30.1	-44.8

$$r \approx \frac{r_0}{(1 - a_\theta t / v_0)^2} \qquad v_0 = \sqrt{\mu / r_0}$$

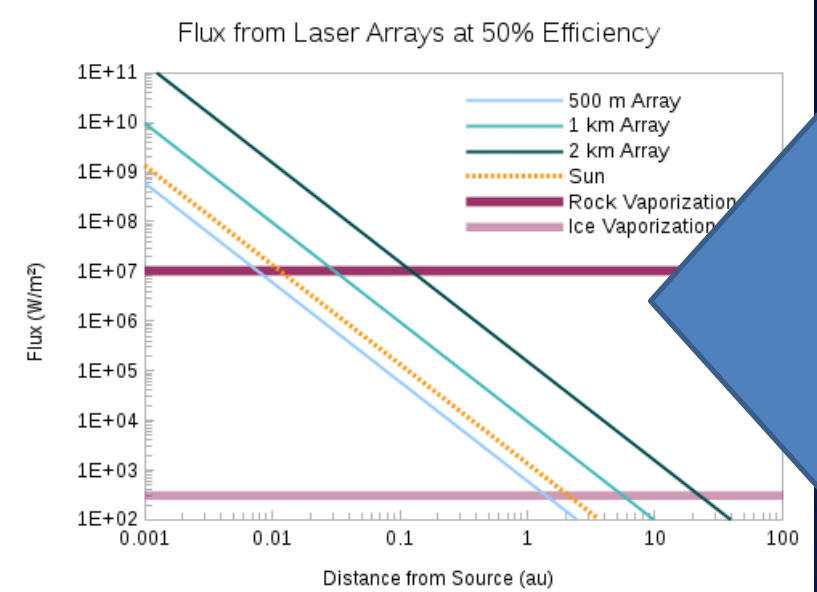
3 to 5 years

1,000,000 ton

10 to 100 kN



SOLUTION, HOW
Localized Sublimation



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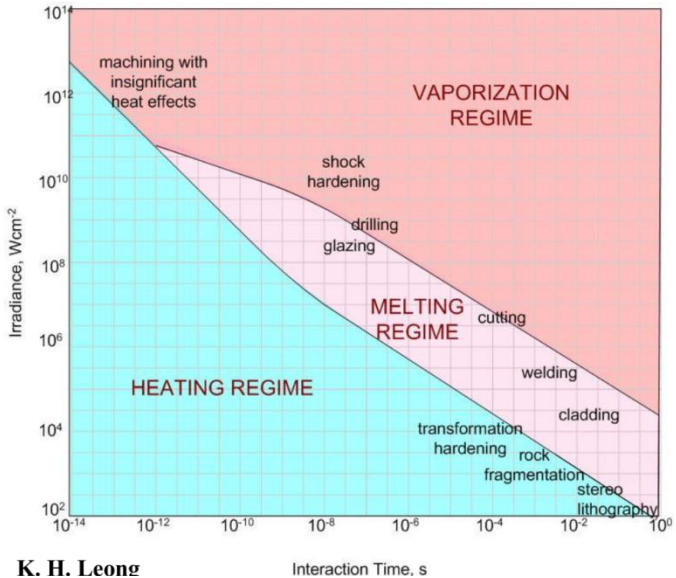
[c]Center for Astrophysics and Space Sciences, Univ. of California, San Diego, CA USA 92093-0424;
[d]Statistics Dept., California Polytechnic State Univ., San Luis Obispo, CA USA 93407-0405

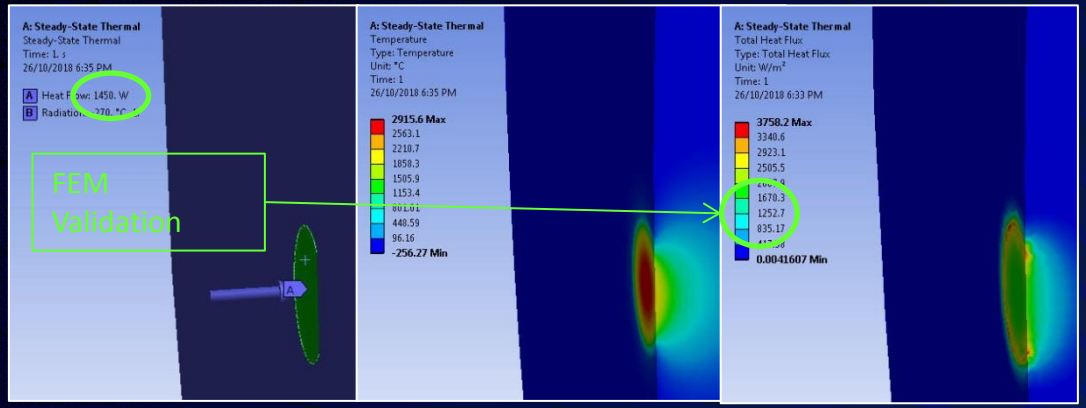
1E7 W/m2
It may be too high for rubble cohesion



K. H. Leong
Argonne National Laboratory, Argonne, Illinois 60439

Operated by The University of Chicago for the United States Department of Energy under Contracts W-31-109-Eng-38

SOLUTION, HOW
Localized Sublimation



$$\Delta \dot{Q} = \dot{m}\,\Delta T = \dot{m}\,(T_I - T_L)$$

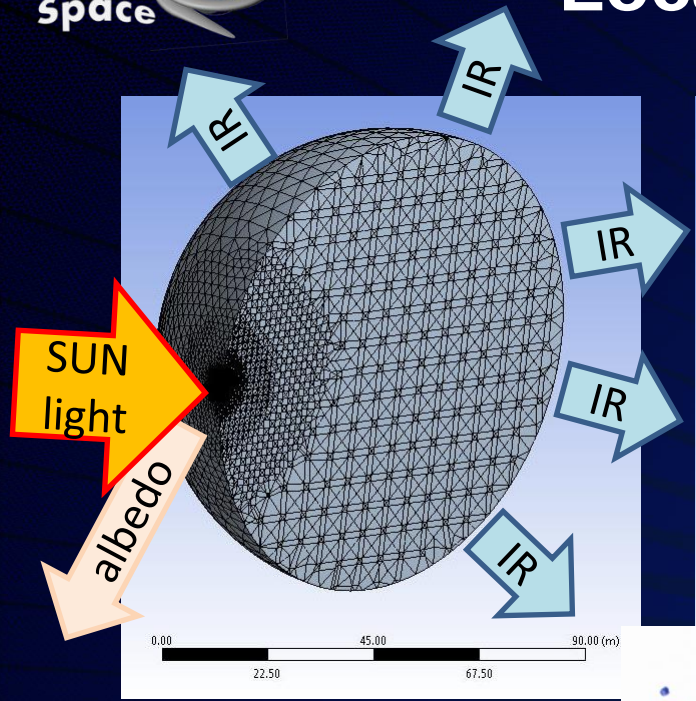
$$\bar{V} = \sqrt{\frac{8\,R\,T_I}{\pi\,M_{ol}}}$$ [Boltzmann]

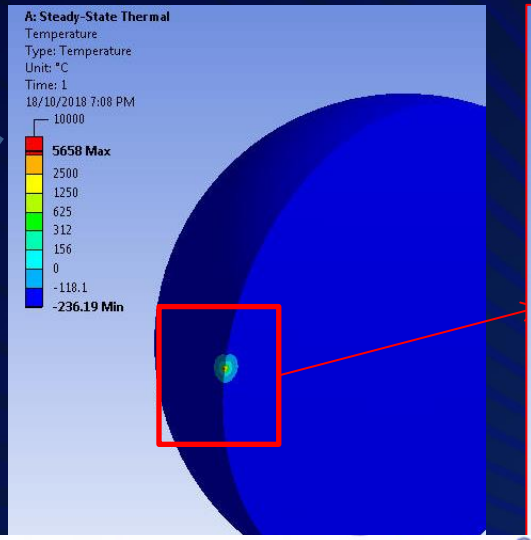
$$\bar{V}_{eff} = \frac{2}{3}\bar{V}$$ $$\left[\int_0^{\pi/2}\int_0^{2\pi} \cos\theta \sin\theta \, d\varphi \, d\theta\right]$$

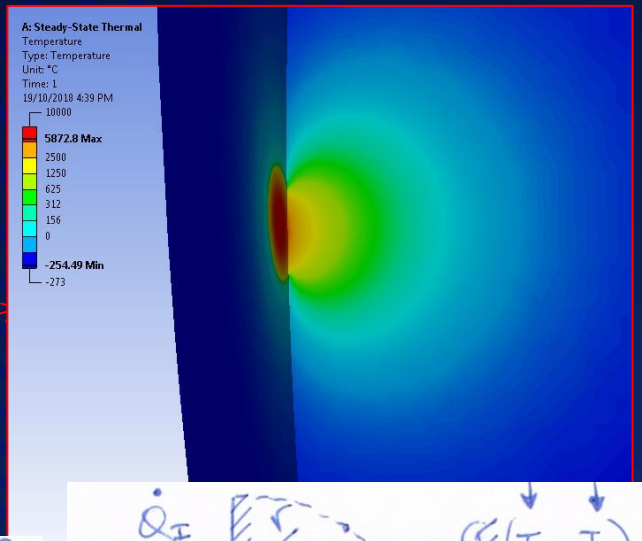
$$F_{eff} = \dot{m} \cdot \bar{V}_{eff}$$ $$\left[I = F \cdot \Delta t = mV \Rightarrow F = \frac{m}{\Delta t}V\right]$$

Asteroid			2011MD	AWGmin	AWGmid	AWGmid	AWGmax
reference case			Llado		focussed	blurred	
asteroid size		**m**	**6**	**20**	**100**	**100**	**1000**
Distance from the Sun		AU	1.5				
Solar constant		W/m2	1300				
Solar energy flux	Qsun	W/m2	867				
Aperture size (square)	**Imir**	**m**	**10**	**60**	**700**	**700**	**20000**
		km	**0.01**	**0.06**	**0.7**	**0.7**	**20**
Aperture surface	Smir	m2	100	3.6E+03	4.9E+05	4.9E+05	4.0E+08
Mirror system efficiency			0.95				
Asteroid albedo			0.2				
Incident energy flow	QI	W	6.59E+04	2.37E+06	3.23E+08	3.23E+08	2.63E+11
		MW	0.1	2	323	323	263467
Vaporization surface	**Svap**	**m2**	**0.3**	**10**	**0.8**	**500**	**30000**
vaporization diameter	d	m	0.6	3.6	1.0	25.2	195.5
Incident energy flux	Qi	W/m2	2.2E+05	2.4E+05	4.0E+08	6.5E+05	8.8E+06
Total Heat of Vaporization	Cvap	J/kg	3.33E+06				
rock density (rubble)	rhor	kg/m3	2000				
rock conduction coefficient	krok	W/mK	0.2				
Dissipated energy flow	Qlost	W	569	3288	930	23249	180086
		W/m2	1898	329	1162	46	6
		%	1%	0.139%	0.0003%	0.007%	0.00007%
Vaporizing heat flow	Q	W	6.53E+04	2367912	3.23E+08	3.23E+08	2.6347E+11
mass flow rate	mdot	kg/s	1.96E-02	7.10E-01	9.68E+01	9.68E+01	7.90E+04
Vaporizing volume rate (rock)	Vrdot	m3/s	9.79E-06	3.55E-04	4.84E-02	4.84E-02	3.95E+01
Vaporization depth rate	dvap	m/s	3.3E-05	3.6E-05	6.1E-02	9.7E-05	1.3E-03
		mm/hour	118	128	217853	349	4742
Ideal Gas Constant	R	J/molK	8.314				
emission Boltzmann average velocity	vavrg	m/s	1376				
Vaporized volume rate (gas)	Vgdot	m3/s	4.13E+02	1.38E+04	1.10E+03	6.88E+05	4.13E+07
axial velocity of hemispherical emission	vax	m/s	917				
axial force	**Fax**	**N**	**18**	**652**	**88823**	**88817**	**72509008**
		kN		**1**	**89**	**89**	**72509**
axial pressure	Pax	Pa	60	65	111029	178	2417
		bar	0.001	0.001	1.110	0.002	0.024
asteroid volume	Vast	m3	113	4187	5.2E+05	5.2E+05	5.2E+08
asteroid density	Rhost	kg/m3	2000	2000	2000	2000	2000
asteroid mass	Mast	kg	226080	8373333	1.05E+09	1.05E+09	1.0467E+12
		ton	226	8373	1.05E+06	1.05E+06	1.05E+09
		Mton			1.0	1.0	1047
		Bton			0.001	0.001	1.0
transfer to Earth time	**TTTE**	**years**	**3**	**3.1**	**2.8**	**2.9**	**3.3**

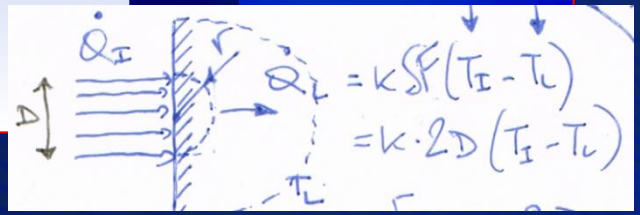
SOLUTION, HOW
Localized Sublimation



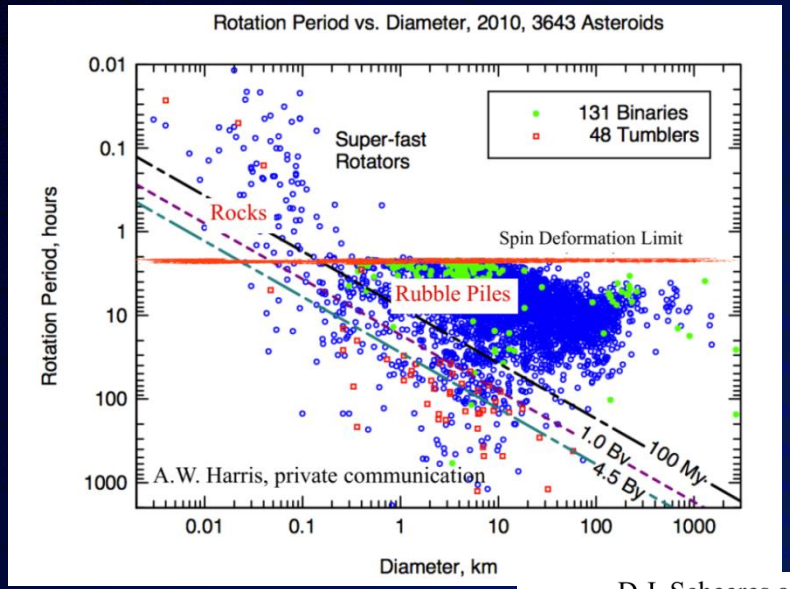


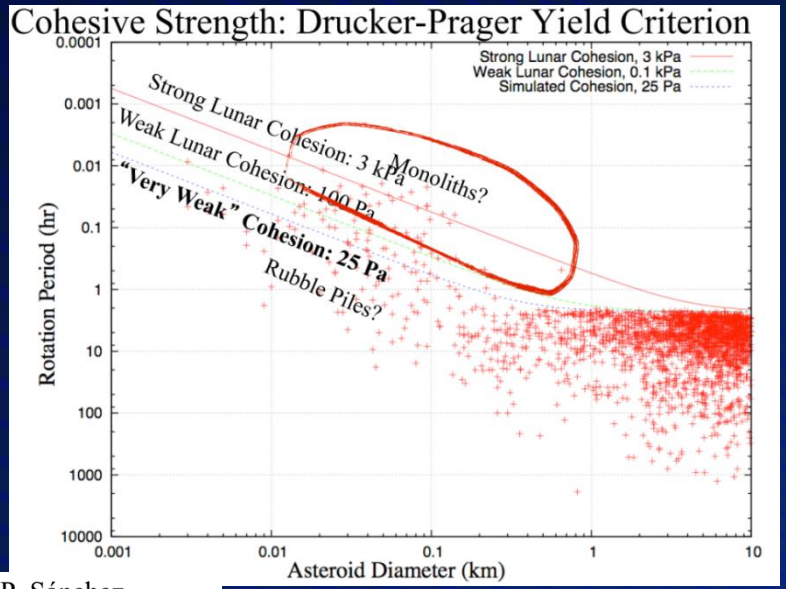


$$\dot{Q}_I = \gamma\left(\frac{S_H}{S_S}\right)(1-\varepsilon_A)\,\dot{\Phi}_S\left(\frac{r_{AU}}{r_A}\right)^2$$



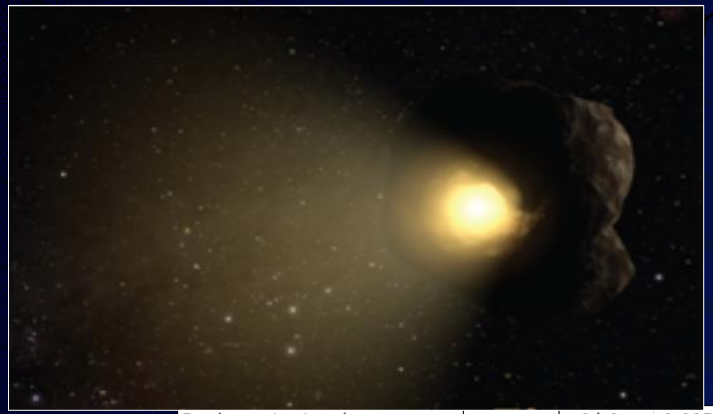
SOLUTION, HOW
Asteroid integrity limits (cohesion and stress)

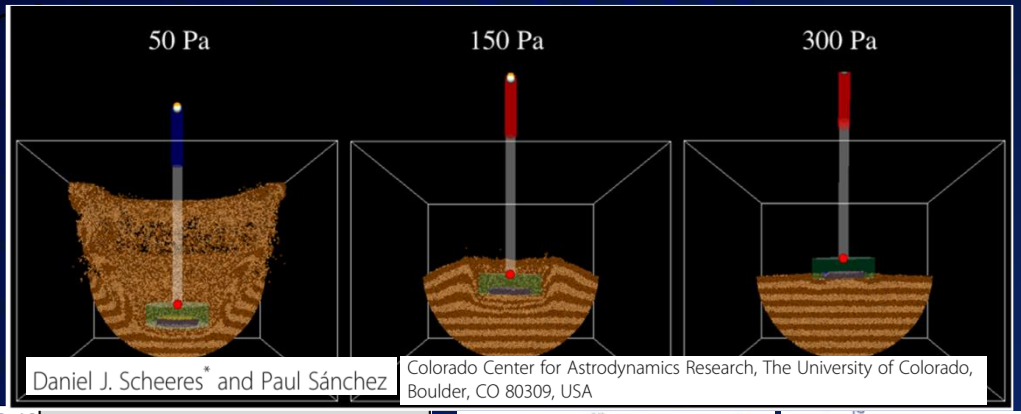




D.J. Scheeres and P. Sánchez
Department of Aerospace Engineering Sciences
The University of Colorado Boulder

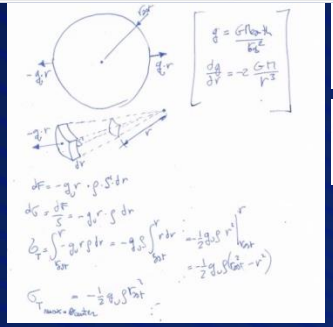
SOLUTION, HOW
Risks: Cohesion, Tidal forces





Earth gravitational constant	mu	m3/s2	3.99E+10				
			LEO	MEO	GEO	above	Moon
Orbital radius	ro	m	7.00E+06	2.10E+07	4.20E+07	6.30E+07	4.00E+08
gravitational gradient	gu	m/s2/m	-2.32E-10	-8.61E-12	-1.08E-12	-3.19E-13	-1.25E-15
asteroid density	rhost	kg/m3	1500				
max tidal stress	sigma0	N/m2					
asteroid radius	rast	m					
		10	-1.7E-05	-6.5E-07	-8.1E-08	-2.4E-08	-9.3E-11
		100	-1.7E-03	-6.5E-05	-8.1E-06	-2.4E-06	-9.3E-09
		1000	-1.7E-01	-6.5E-03	-8.1E-04	-2.4E-04	-9.3E-07
		10000	-1.7E+01	-6.5E-01	-8.1E-02	-2.4E-02	-9.3E-05

NEGLIGIBLE

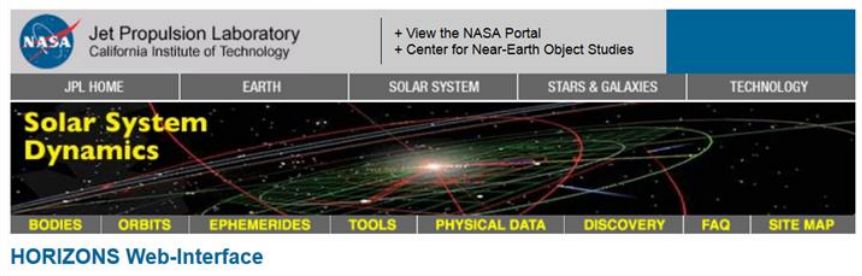


$$\frac{\Delta g}{e} = -2 * G * M_{Earth} * \frac{1}{r^3}$$

$$= -\frac{2 M_E}{r_{geo}^3}$$

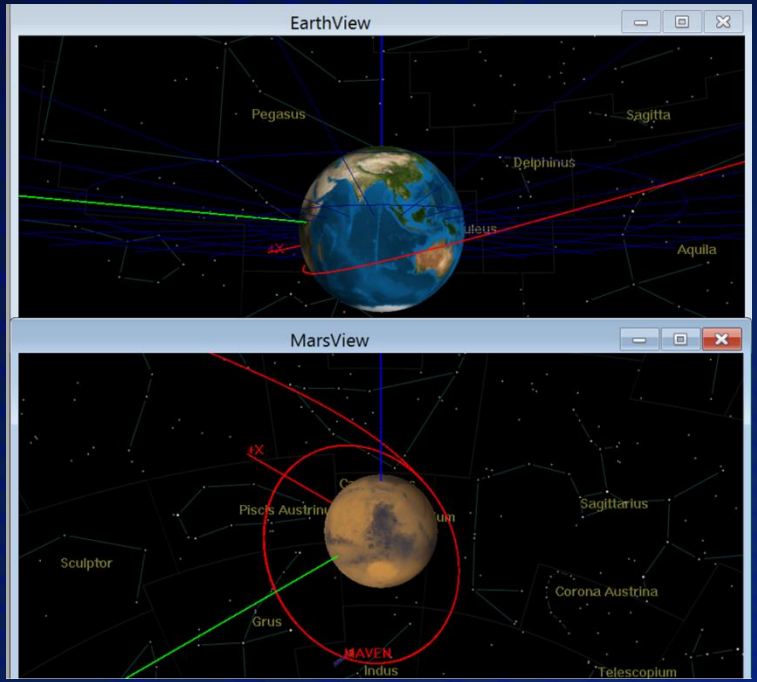
UNITED NATIONS
Office for Outer Space Affairs

SOLUTION, HOW
ASTEROID List, Selection and Simulations

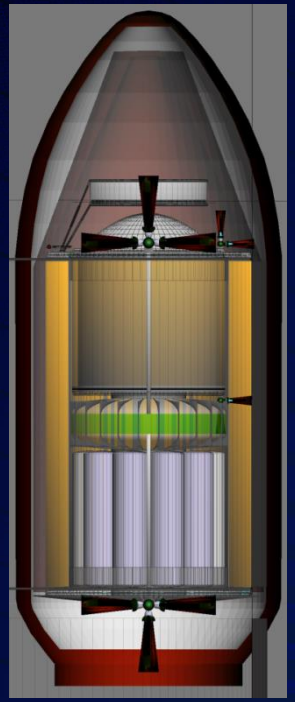


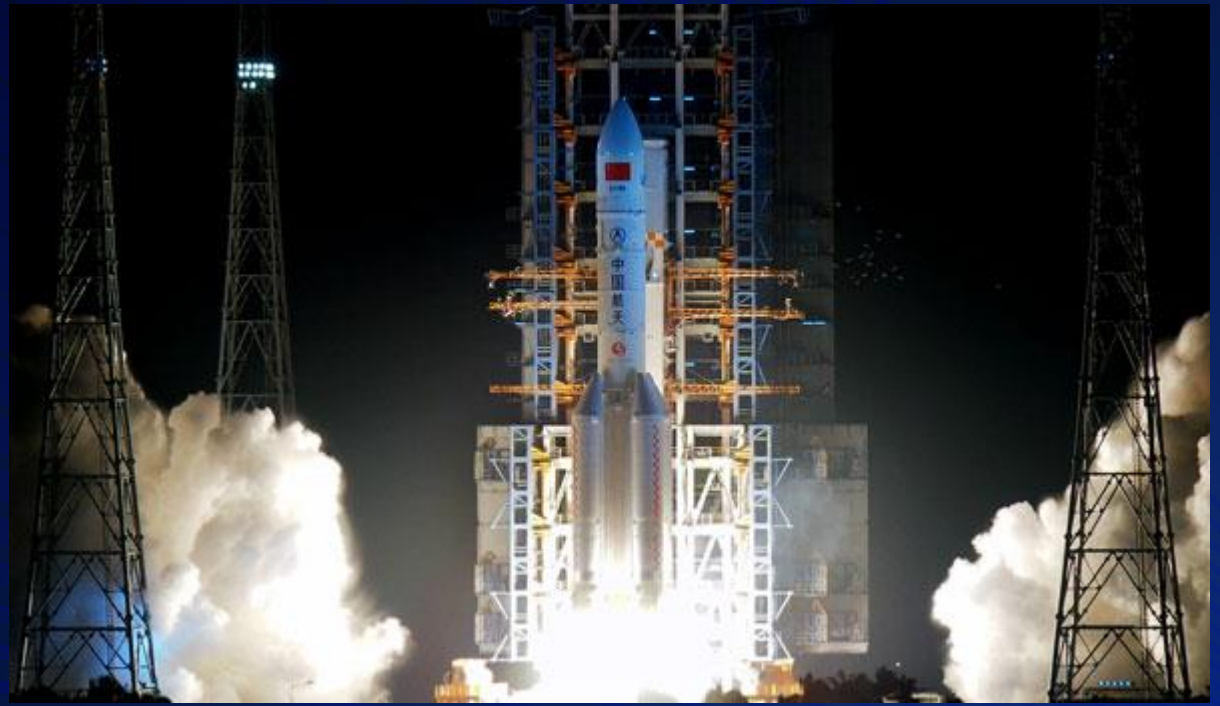

```
JPL/HORIZONS                 162173 Ryugu (1999 JU3)          2018-Oct-24 07:22:48
Rec #:  162173 (+COV) Soln.date: 2018-Mar-28_16:14:14    # obs: 725 (1986-2016)

IAU76/J2000 helio. ecliptic osc. elements (au, days, deg., period=Julian yrs):

  EPOCH=  2455907.5 ! 2011-Dec-12.00 (TDB)          Residual RMS= .30546
   EC= .1902257533711703   QR= .9633081094119196   TP= 2455902.2563366606
   OM= 251.6197109778495   W=  211.4258497031505   IN= 5.883742390778817
   A= 1.189600821984975    MA= 3.98324473954508    ADIST= 1.41589353455803
   PER= 1.29751            N= .759630123           ANGMOM= .018419537
   DAN= 1.36873            DDN= .98643             L= 102.9110866
   B= -3.0638234           MOID= .00063831         TP= 2011-Dec-06.7563366606

Asteroid physical parameters (km, seconds, rotational period in hours):
   GM= n.a.                RAD= n.a.               ROTPER= 7.627
   H= 19.3                 G= .150                 B-V= n.a.
                           ALBEDO= n.a.            STYP= Cg

Asteroid non-gravitational force model (AMRAT= m^2/kg;A1,A2,A3=au/d^2;R0=au):
   AMRAT=  0.
   A1= 0.                  A2= -3.371880211489E-14 A3= 0.
 Non-standard or simulated/proxy model:
   ALN=  1.          NK=  0.       NM=  2.       NN=  5.093    R0=  1.

ASTEROID comments:
1: soln ref.= JPL#120, PHA  OCC=0
2: source=ORB; Yarkovsky a priori (-25+-25)e-15 au/d^2
```

GMAT
- General
- Mission
- Analysis
- Tool

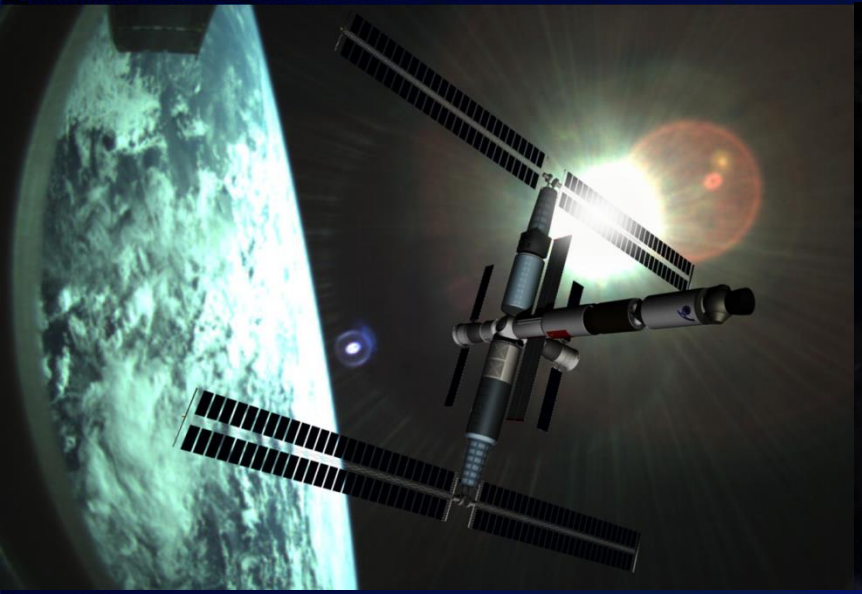


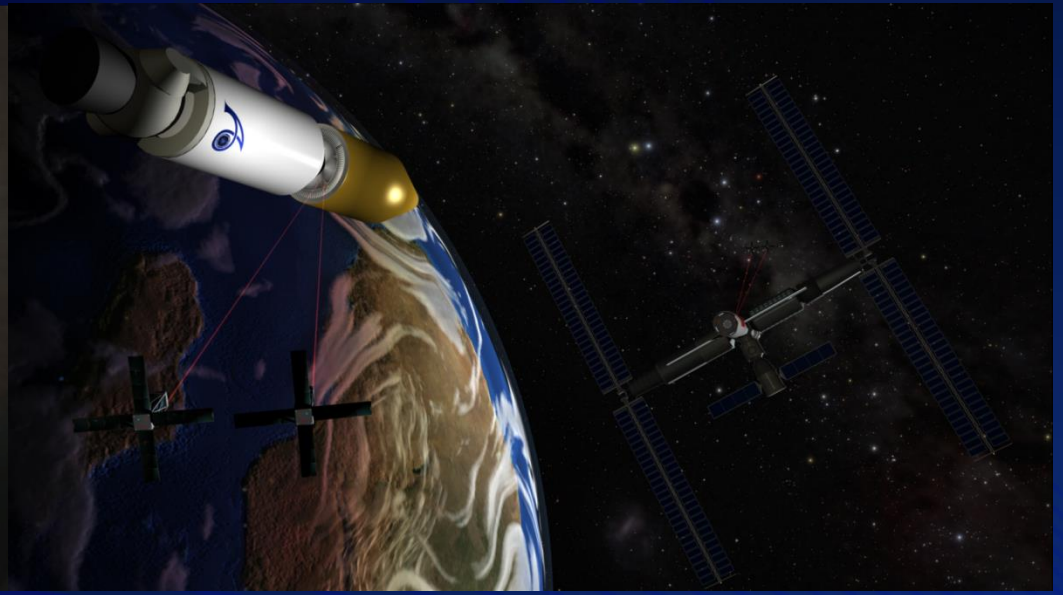
SOLUTION, HOW
RAA MISSION START



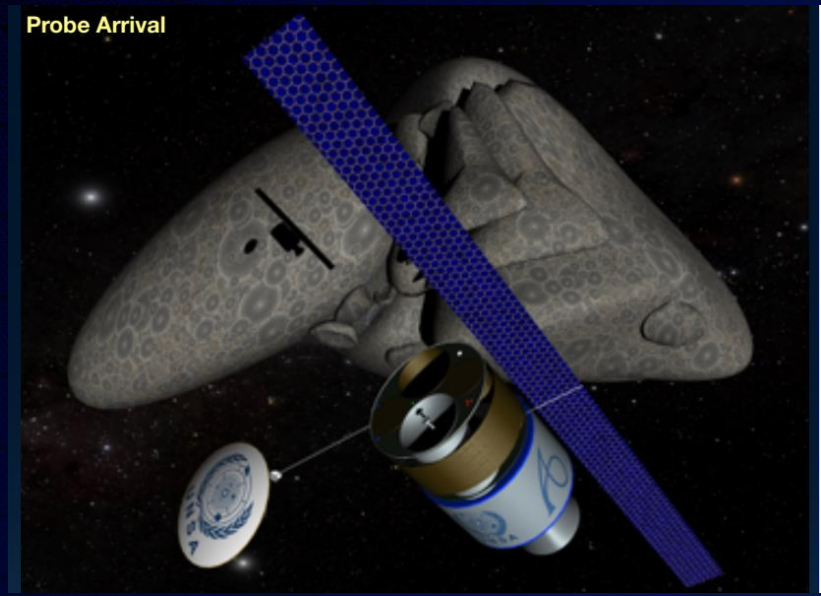


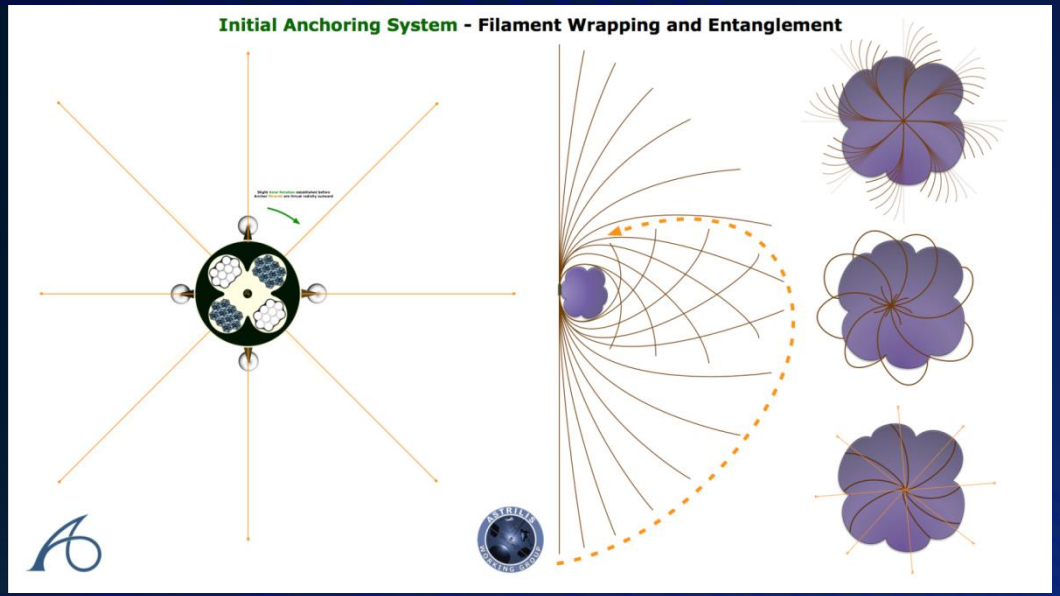
SOLUTION, HOW
UN and CSS
ACTIVITIES at CSS





SOLUTION, HOW
Probes and Initial Anchoring





SOLUTION, HOW

Mirrors Unfurling

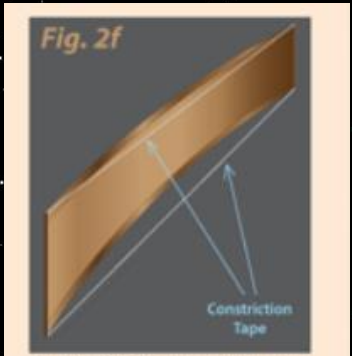


Fig. 2f - Single strip deployment

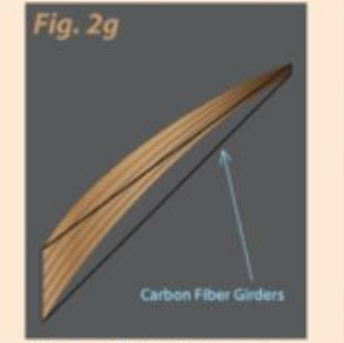
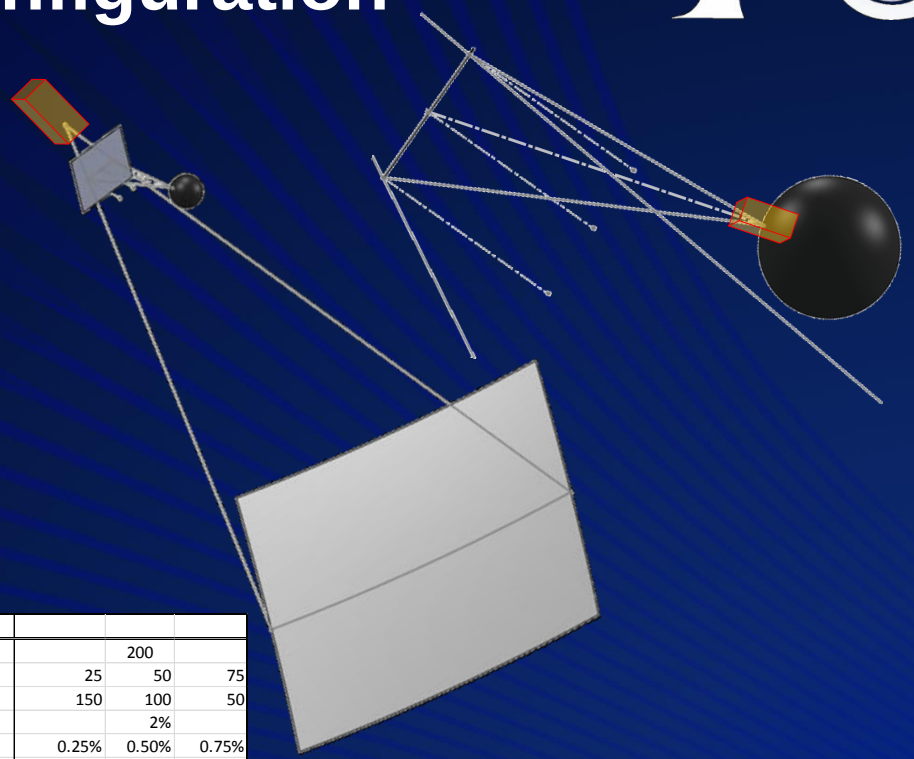


Fig. 2g - Multistrip Structuring

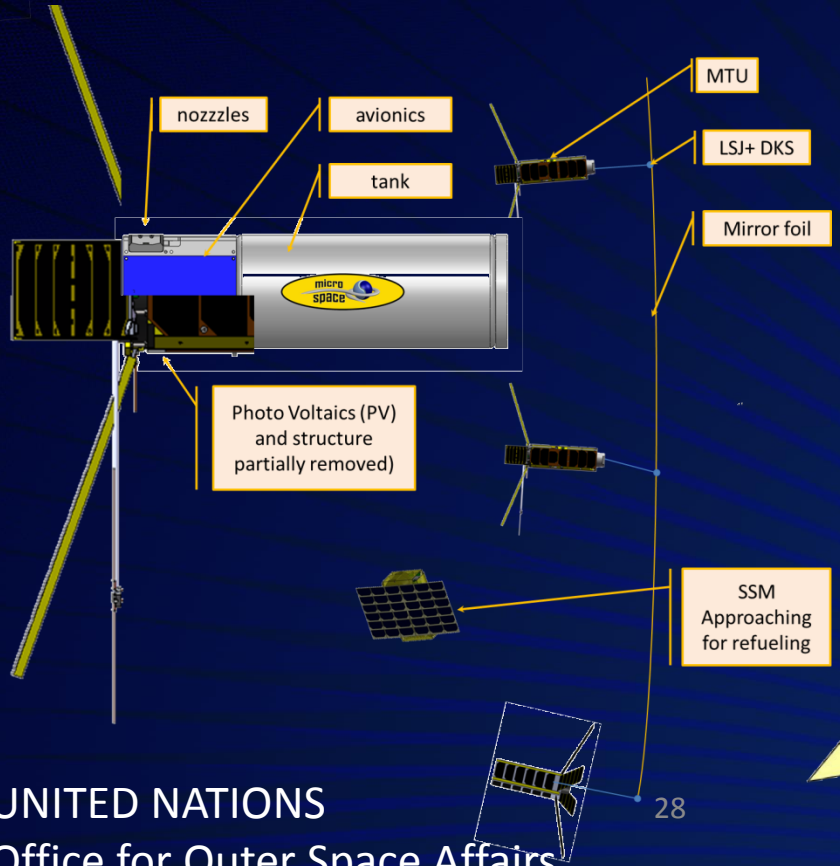
SOLUTION, HOW
Mirrors Configuration

Overall Configuration						
Focal length	L1	m	100000	50000	25000	our choice
		km	100	50	25	
Primary Aperture	A1	m	10000	10000	10000	as per required energy
		km	10	10	10	
f/number	f/#		10	5	2.5	
Asteroid diameter	D	m	1000	1000	1000	1 Bton
Secondary Aperture	A2	m	1000	1000	1000	should be not too big
Primary to secondary distance		m			22500	linear proportion
Secondary position	l2	m	10000	5000	2500	consequence
		km	10	5	2.5	
Focal Spot Diameter	d	m	0.3	1.1	4.5	Circle of least confusion
Ideal Focal Spot position error	ferr	%	30%	30%	30%	to keep best focusing
		m	0.1	0.3	1.4	
Actual focusing surface		m2	0.1	1.7	27	
Ideal pointing precision	alerr	rad	8.4E-07	6.8E-06	5.4E-05	to keep same heating point
		deg	4.8E-05	3.9E-04	3.1E-03	
		arcsec	0.2	1.4	11	
			unfeasible	extreme	very difficult	overall very difficult
Possible pointing precision		deg	0.5	0.5	0.5	a guess from experience
		rad	0.01	0.01	0.01	
Focal Spot uncertain position		m	873	436	218	consequence
Required focusing area diameter		m	195			as per required stress



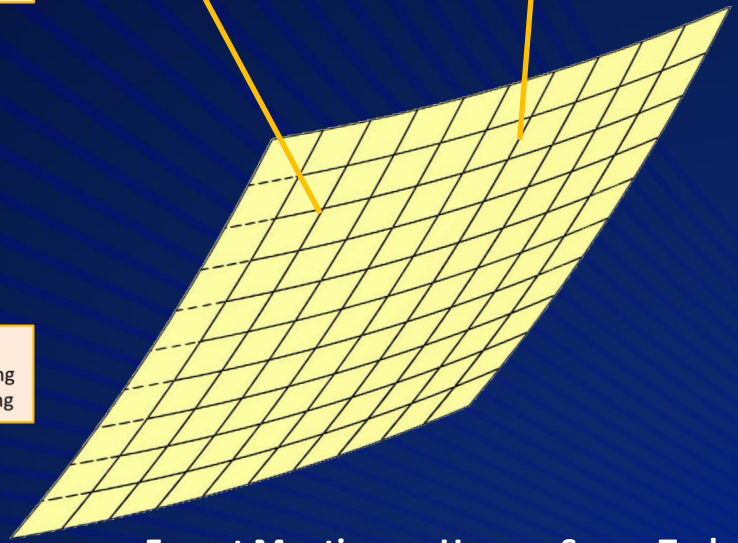
Tolerances Budget					
total		m		200	
Section Position Error	eps	m	25	50	75
Curvature Error	rho	m	150	100	50
Total relative to size		%		2%	
Section Position relative to size		%	0.25%	0.50%	0.75%
Curvature relative to size		%	1.50%	1.00%	0.50%

SOLUTION, HOW MIRRORS CONTROLS



One MTU at each node in Push-Pull configuration

Cured sections Stiffened by Girders

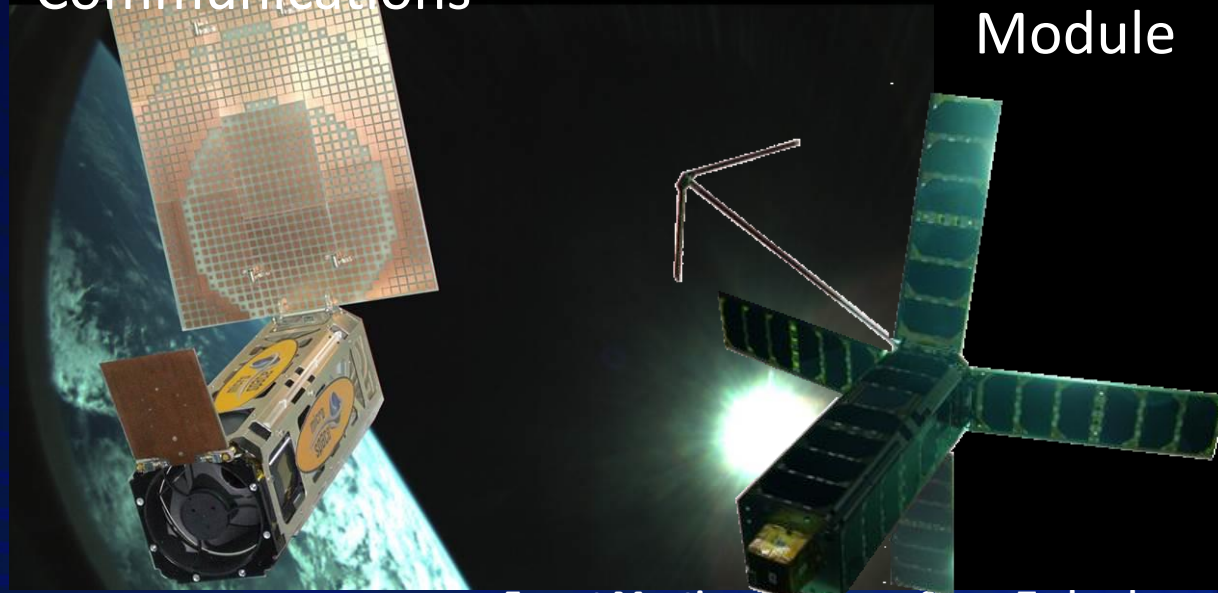


SOLUTION, HOW
Nano-Spacecrafts

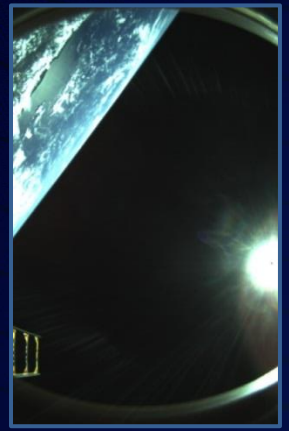
Heritage and Precursors

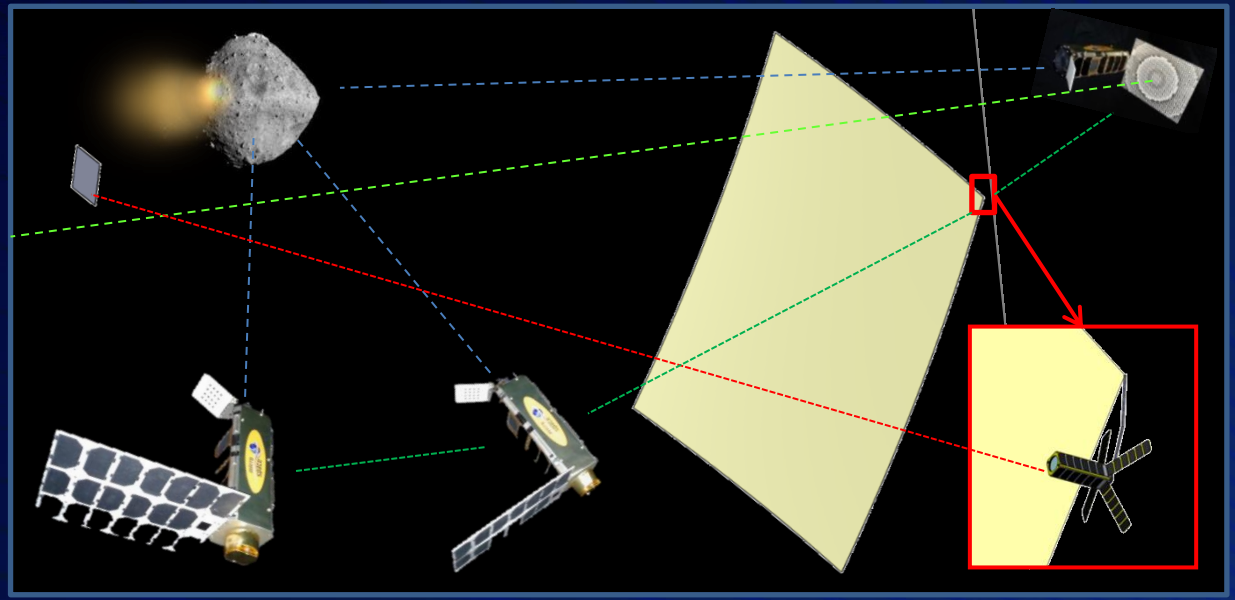
Observer and Long Range Communications

MicroThruster Module

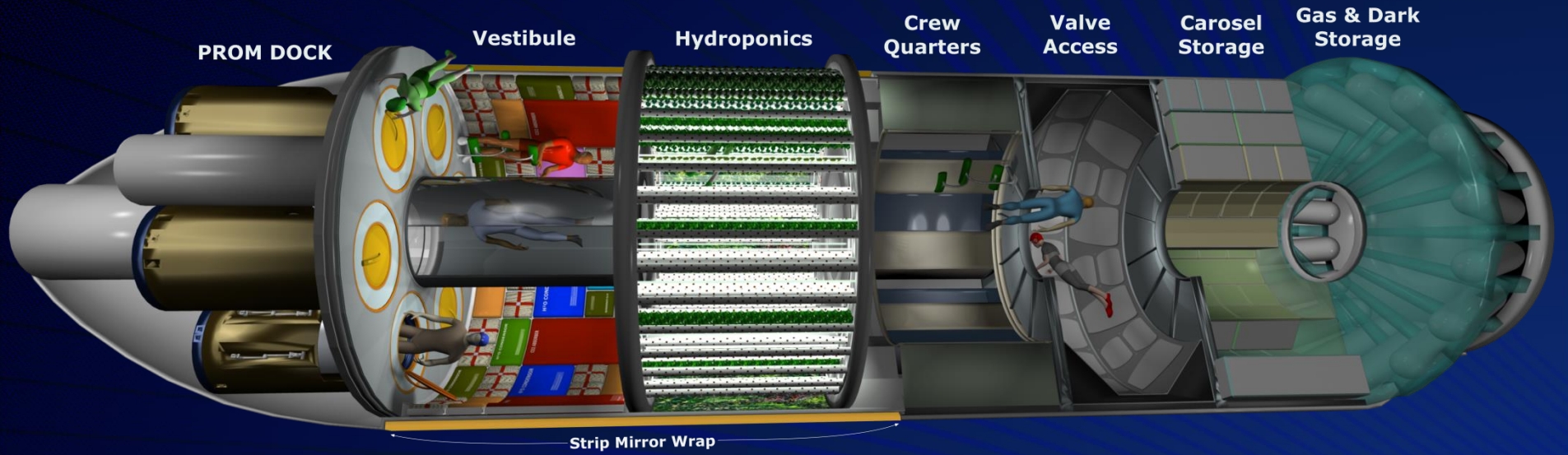


SOLUTION, HOW
VISUAL MONITORING AND COMMUNICATIONS





SOLUTION, HOW
BOOTSTRAP MISSION



SOLUTION, HOW
UN SPACE AGENCY

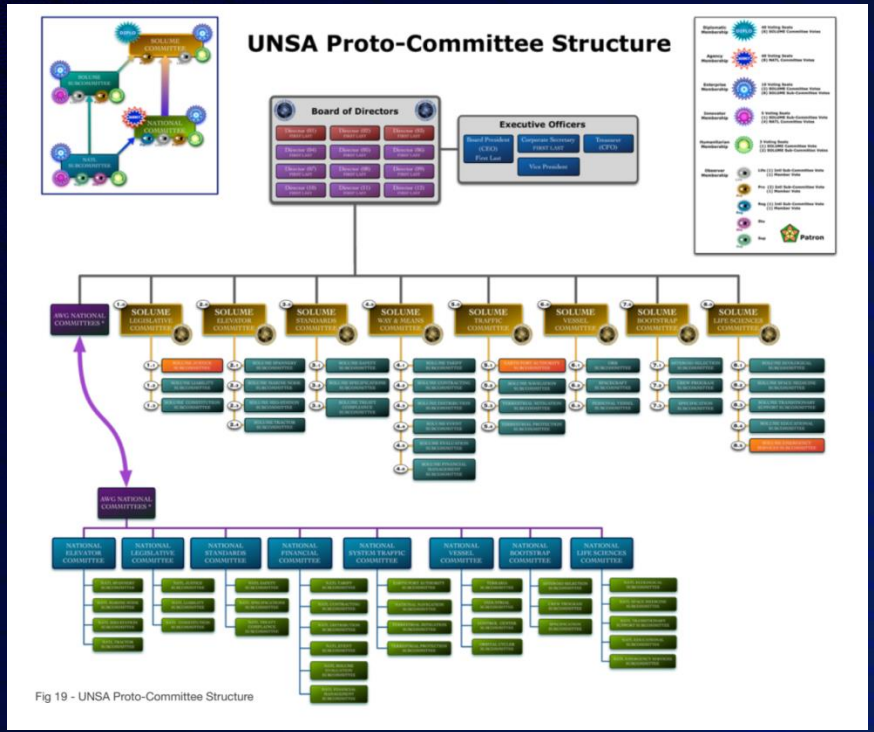


Fig 19 - UNSA Proto-Committee Structure

The United Nations Space Agency (UNSA) is needed to govern the exploration, ownership, use and distribution of the limitless potential offered by our solar system to prevent the creation of monopolies, as was done in the 18th and 19th centuries.

Usage fees paid to the UNSA will be used to help fund activities that support the 17 SDGs

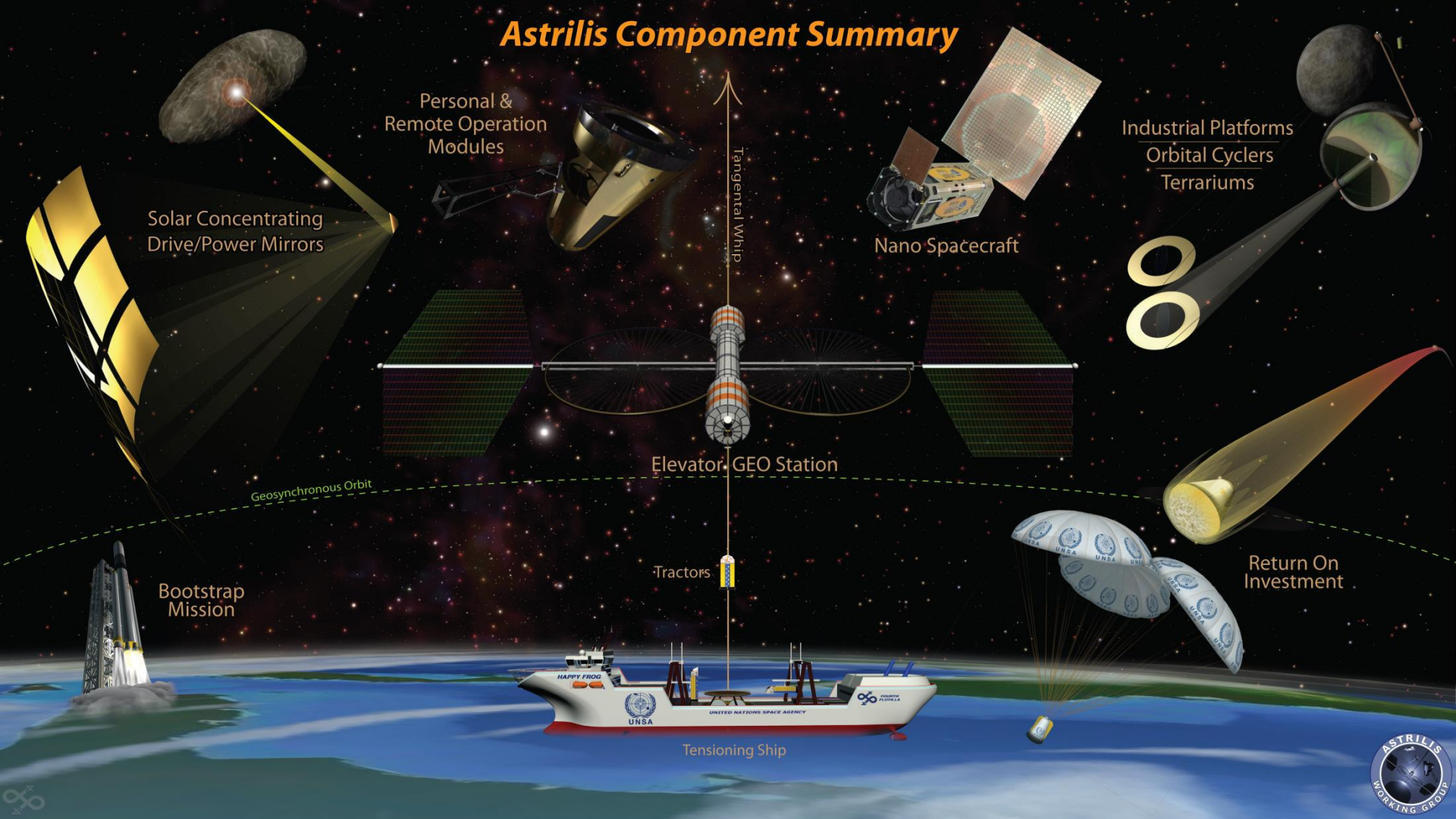
ASTRILIS SUPPORTS
12 of the 17 SDGs

- ✓ ENERGY PRODUCTION
- ✓ INDUSTRIAL RELOCATION
- ✓ **ABUNDANCE OF MATERIALS**
- → EQUITABLE DISTRIBUTION ←
- ✓ **NEW HABITAT FOR PEOPLE**
- ✓ TECHNOLOGY PROGRESS
- ✓ NEW EMPLOYMENT

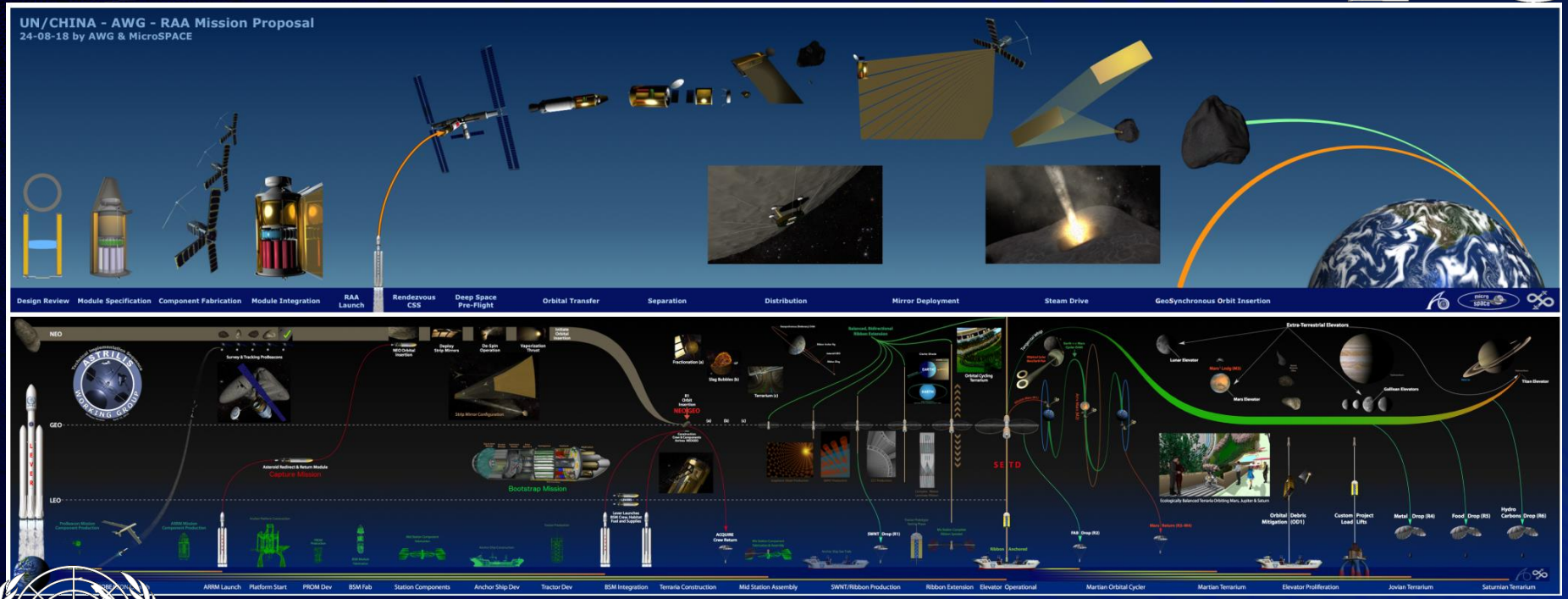
UNITED NATIONS
Office for Outer Space Affairs

Expert Meeting on Human Space Technology
4 – 6 December, VIC, Vienna, Austria

Astrilis Component Summary



TIMELINE


UN/CHINA - AWG - RAA Mission Proposal
24-08-18 by AWG & MicroSPACE
Design Review
Module Specification
Component Fabrication
Module Integration
RAA Launch
Rendezvous CSS
Deep Space Pre-Flight
Orbital Transfer
Separation
Distribution
Mirror Deployment
Steam Drive
GeoSynchronous Orbit Insertion
NEO
GEO
LEO
Bootstrap Mission
SETD
ARRM Launch
Platform Start
PROM Dev
BSM Fab
Station Components
Anchor Ship Dev
Tractor Dev
BSM Integration
Terraria Construction
Mid Station Assembly
SWNT/Ribbon Production
Ribbon Extension
Elevator Operational
Martian Orbital Cycler
Martian Terrarium
Elevator Proliferation
Jovian Terrarium
Saturnian Terrarium

ASTRILIS IS A HIGH IMPACT INITIATIVE

The Astrilis Working Group offers a platform that empowers **international collaboration** to implement solutions that **PRESERVE**, **SUSTAIN** and **ENHANCE** all life on Earth!

UNITED NATIONS
Office for Outer Space Affairs

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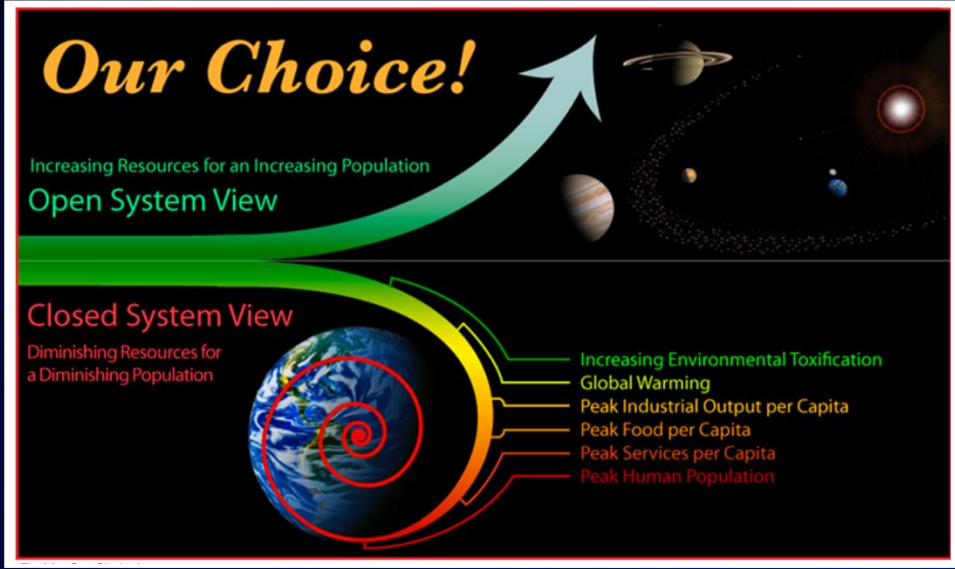
It's Time to Act !



UNSA

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dwight.prouty@astrilis.org , bob.roth@astrilis.org


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