

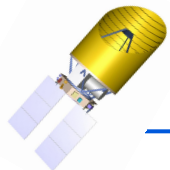
New Worlds Observer, 2nd MDL Study (NWO-2)

Systems Overview

Mr. Anel Flores, Aerospace Systems Engineer

25 - 29 August 2008

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NWO-2 Mission Overview (1 of 5)



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- **Science & Mission Overview:**
 - Direct Detection and Spectroscopy of Exoplanets
 - Planets typically <0.1 arcsec from star, 10^{10} times fainter
 - Similar to a firefly next to a searchlight
 - ~150-200 observations over a 5 year lifetime
 - Two spacecraft free-flying system at Earth-Sun L2
 - Specially shaped star shade efficiently removes central star light (by a factor of 10^{10} to reveal planets using a conventional telescope
 - Competing concepts typically have extreme telescope stability requirements
 - Essentially this burden is transferred to the star shade
- **Science Telescope Spacecraft (STS) Payload:**

Spacecraft Telescope and Instruments	
1.	Optical Telescope Assembly (4-m)
2.	Exo-camera
3.	Exo-Spectrometer
4.	UV instrument
5.	GA WFC/ Guider
6.	Shadow Sensor Assembly



- Star shade Spacecraft (S³) Payload:

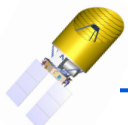
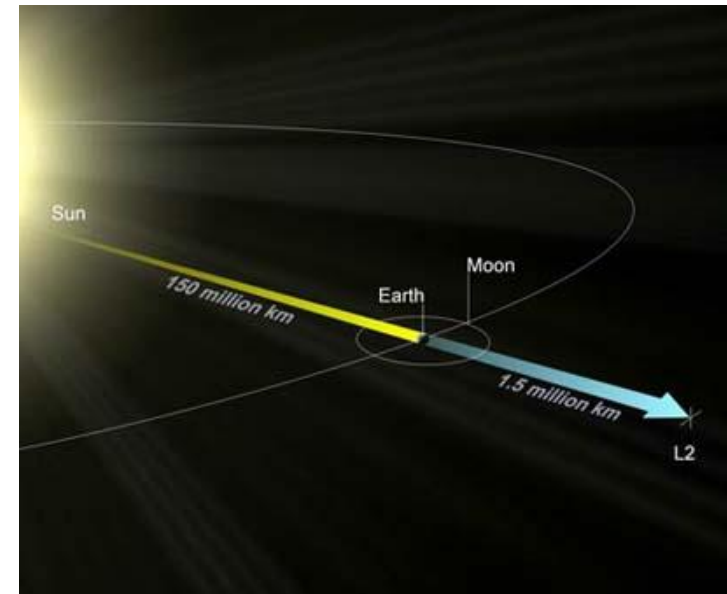
Spacecraft Telescope and Instruments	
1.	Astrometric Sensor (includes laser beacon)
2.	Star Shade

- NASA Flagship Mission

- Launch Date: November 2018

- Launch & Orbit Information:

- Two spacecraft to be launched from the Eastern Range (KSC) on a direct transfer to a Earth-Sun L2 libration
- **Orbit:** Large amplitude halo orbit about L2
- **Launch Energy, C3:** $-0.5 \text{ km}^2/\text{s}^2$
- Two S/C in formation about L2 approximately 80 Mm (80,000 km) from each other

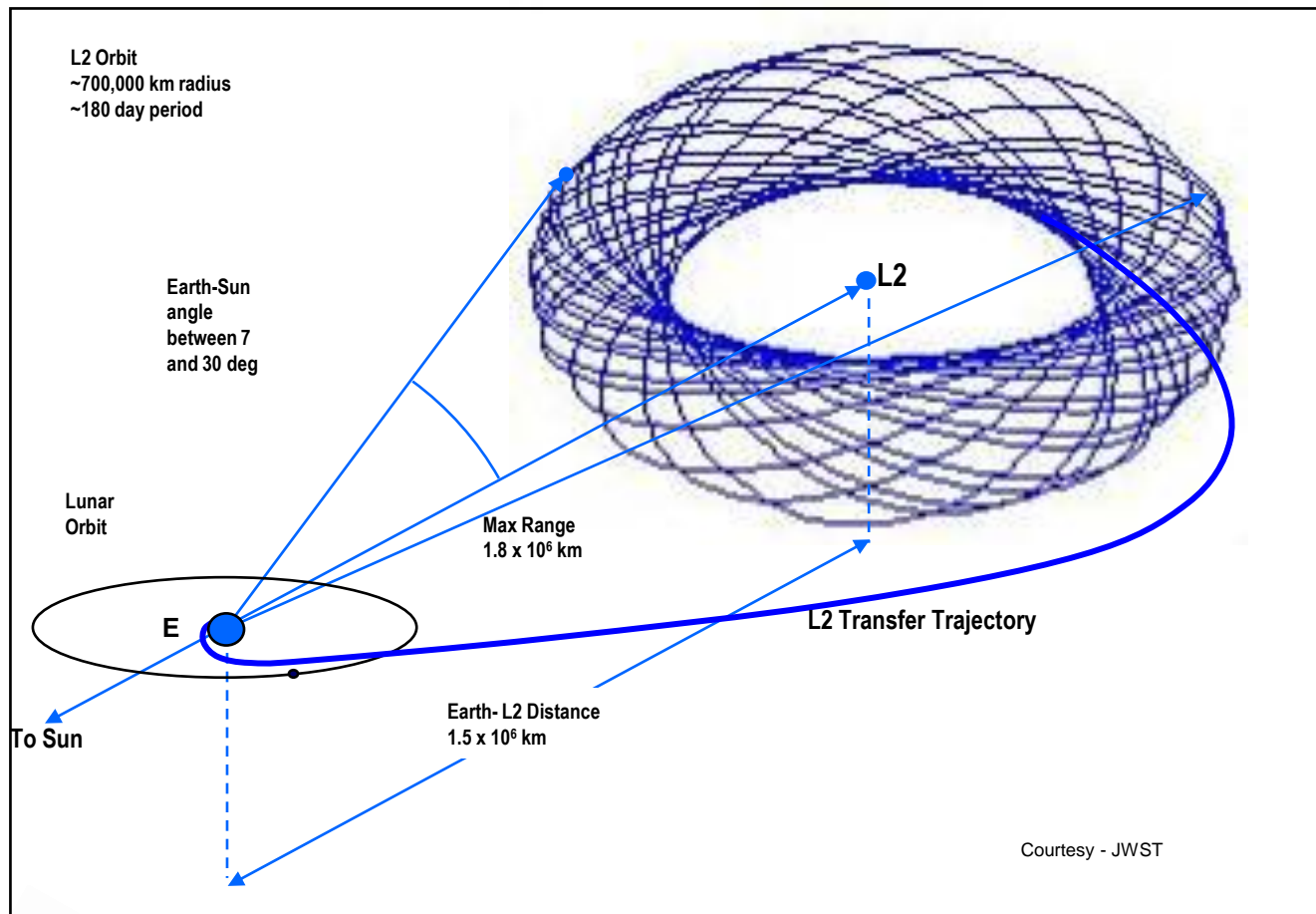


NWO-2 Mission Overview

L2 Orbit (3 of 5)

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Nominal Mission Launch Energy, C3: $-0.5 \text{ km}^2/\text{sec}^2$



Lagrange point L2

- 1.5 million km along the Sun-Earth axis
- Metastable – requires some station-keeping

Advantages

- Thermally stable
- Small stray light source from the Earth and Moon
- No eclipses – continuous observing

This diagram was borrowed from JWST and is representative of the NWO-2 trajectory and orbit.

- **Launch Vehicle Performance:** Direct insertion to L2 orbit
- **Performance C3:** = $-0.5 \text{ km}^2/\text{s}^2$
- **Two spacecraft launched from two Atlas V (551) launch vehicles**
 - STS to be launched first
 - Star Shade spacecraft to be launched 6 months later
- **Launch Vehicle:** Atlas V (551)
 - Med Fairing (5.4-m by 23.4-m) for STS
 - Large Fairing (5.4-m by 26.5-m) for S³
- **Launch Site:** Eastern Range: NASA Kennedy Space Flight Center
 - Coordinates: 28.5 N, 80.5 W
 - Available inclinations 28.5 to 57

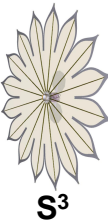


Atlas V (551)



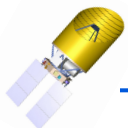


NWO-2 Mission Overview (5 of 5)



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- **Design Reliability**
 - Class A mission; fully redundant design, critical Single Point Failures (for Level 1 requirements) are not permitted unless authorized by formal waiver. (*Class A in accordance with NPR 8705.4 Risk Classification for NASA Payloads*)
- **Mission lifetime:**
 - **Science Telescope Spacecraft (STS)**
 - **Nominal:** 5 years (excludes ~120 days months for cruise and checkout)
 - **Goal:** 10 yrs
 - **Consumables:**
 - Solar arrays: sized for operation through 10 years
 - Propellant: sized for 10 years
 - **Star Shade Spacecraft (S³)**
 - **Nominal:** 4 years (excludes ~120 days months for cruise and checkout)
 - **Goal:** 4+ yrs
 - **Consumables:**
 - Solar arrays: sized for operation through 5 years
 - Propellant: sized for 5+ years



STS

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NWO-2

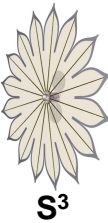
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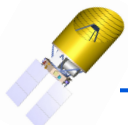


NWO-2 Study Approach



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- Evaluate the Science Telescope Assembly (STS) spacecraft and the Star Shade Spacecraft (S³) buses using the provided top-level design information, payload instrument and mission requirements.
- Assume contractors will build the spacecraft
- Change spacecraft bus components only as necessary with collaboration from the customer, and Ball Aerospace and Northrop Grumman representatives
- Identity tall poles, technical issues and critical future work.
- Estimate costs
- Provide relevant technical comments and recommendations



STS

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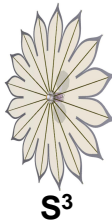
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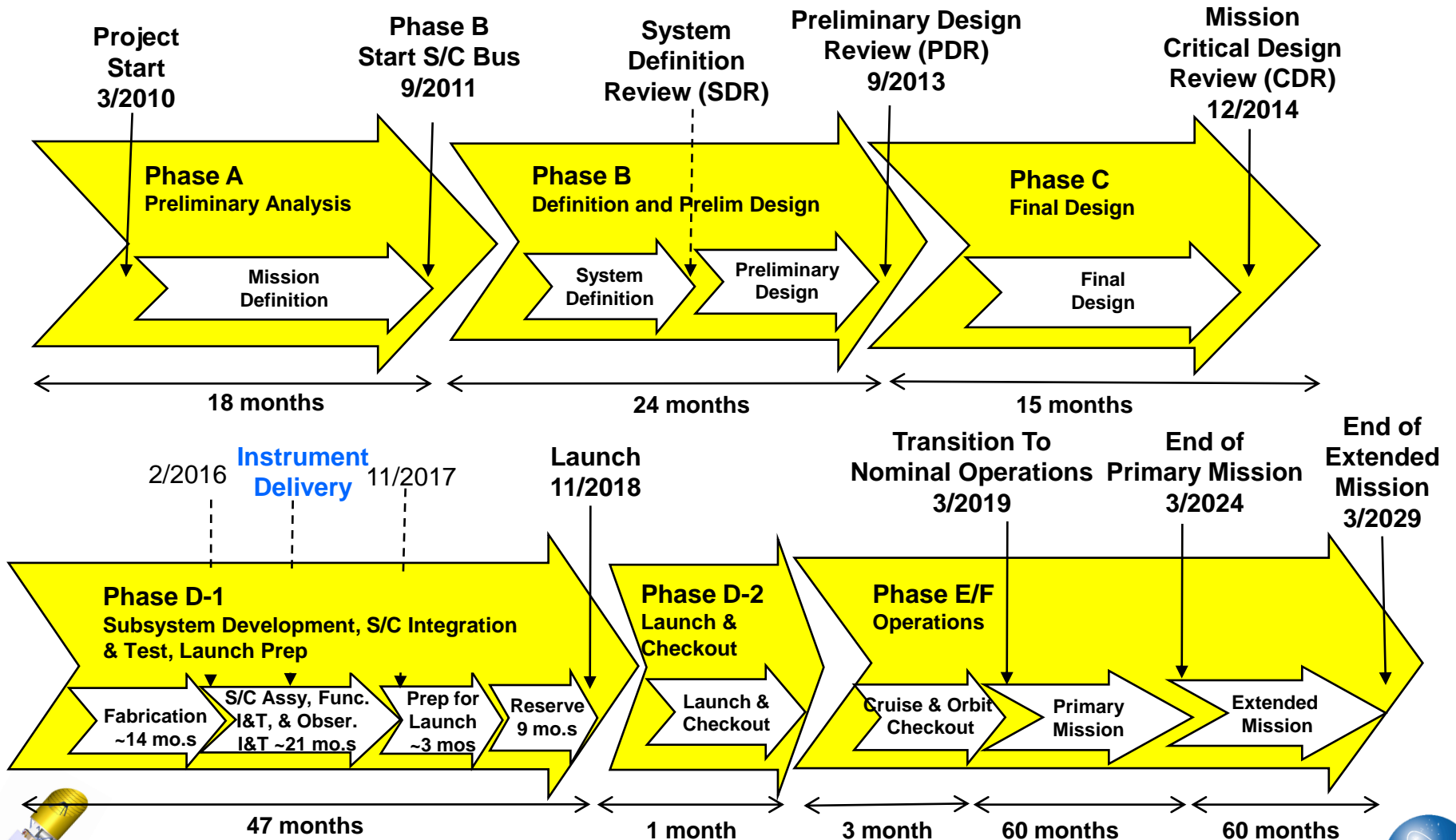


NWO-2 Spacecraft Lifecycle



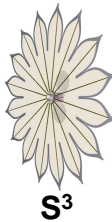
Timeline not to scale

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Attitude Control Phases & Requirements



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Mission phase	S ³ ACS requirements	STS Requirements	Notes/Rationale/Issues
Lost in Space	0.5° control 0.5° knowledge	0.5° control 0.1° knowledge	May need to point laser beacon from STS to S ³ May be looser requirement
Retargeting	0.5° control 0.1° knowledge	0.25° control 0.1° knowledge	Occasionally point laser beacon to S ³ Point JMAPS w/o exercising bearings
Transition 1 (AS position control)	.25° control (S ³) .1° knowledge (S ³) 50.0 mas knowledge(JMAPS) 100 mas/s jitter control (gimbals)	.1° control .1° knowledge ↓ 10 as control 10 as knowledge 1 as/s jitter control	Pointing knowledge of JMAPS boresight provided by JMAPS. Fine pointing control of JMAPS provided by gimbals Jitter control/isolation will be necessary – trade for MDL. Fallback for jitter uses accelerometers on Optical Bench
Transition 2 (SS position control)	.25° control (S ³) .1° knowledge (S ³) 5.0 mas knowledge(JMAPS) 50 mas/s jitter control (gimbals)	10 as control 10 as knowledge 1 as/s jitter control ↓ 2mas/2mas/1.0as knowledge	Maintain AS lock on beacon and consider combining AS and SS signals STS may transition from fine pointing to science pointing STS science pointing knowledge provided by ST FGS
Science	0.25° control 0.1° knowledge	2mas/2mas/1.0 asec (R/P/Y) knowledge	ST science pointing knowledge provided by ST FGS (Yaw axis along ST boresight)



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NWO-2 STS Delta V Budget

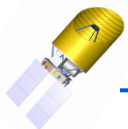


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NWO-2 STS DELTA-V BUDGET					
Maneuver		Delta V (m/s)	ACS Tax	Margin	Effective ΔV (m/s)
1	Launch Window	0.0	0.0%	0.0%	0.0
2	Mid-Course Correction (MCC) #1	30.0	0.0%	30.0%	39.0
3	Mid-Course Correction (MCC) #2	3.0	0.0%	30.0%	3.9
4	L2 Injection	71.0	0.0%	30.0%	92.3
5	Orbit Maintance	40.0	0.0%	30.0%	52.0
6	ACS Momentum Dumping	4.0	0.0%	30.0%	5.2
Total Delta-V Budget		148.0	0.0%	30.0%	192.4

NOTES:

- (1) The Effective Delta V values shown above include 30% margin.
- (2) The propellant is sized for a 10 year life.
- (3) The Delta V budget is conservative.



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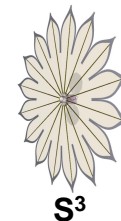
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NWO-2 S³ Delta V Budget



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NWO-2 S ³ DELTA-V BUDGET (Chemical)					
Maneuver		Delta V (m/s)	ACS Tax	Margin	Effective ΔV (m/s)
1	Launch Window	0.0	0.0%	0.0%	0.0
2	Mid-Course Correction (MCC) #1	30.0	0.0%	30.0%	39.0
3	Mid-Course Correction (MCC) #2	3.0	0.0%	30.0%	3.9
4	L2 Injection & Attitude Slew, phase w/ STS	71.0	0.0%	30.0%	92.3
5	Target Station-keeping (Orbit & Pointing)	142.8	0.0%	30.0%	185.7
6	Momentum Unloading	14.2	0.0%	30.0%	18.5
Total Delta-V Budget		261.0	0.0%	30.0%	339.4

NWO-2 S ³ DELTA-V BUDGET (Electric Propulsion)		
Maneuver		Delta V (m/s)
1	Target Slewing (Orbit)	7900.0
2	Margin (~20 Targets)	2400.0
Total Delta-V Budget		10300.0

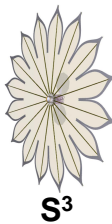
NOTES:

- (1) For the chemical system shown above the effective Delta V values include a 30% margin.
- (2) In both cases shown the propellant is sized for about ~5.3 years
- (3) The chemical Delta V budget is conservative.

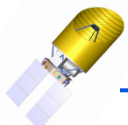
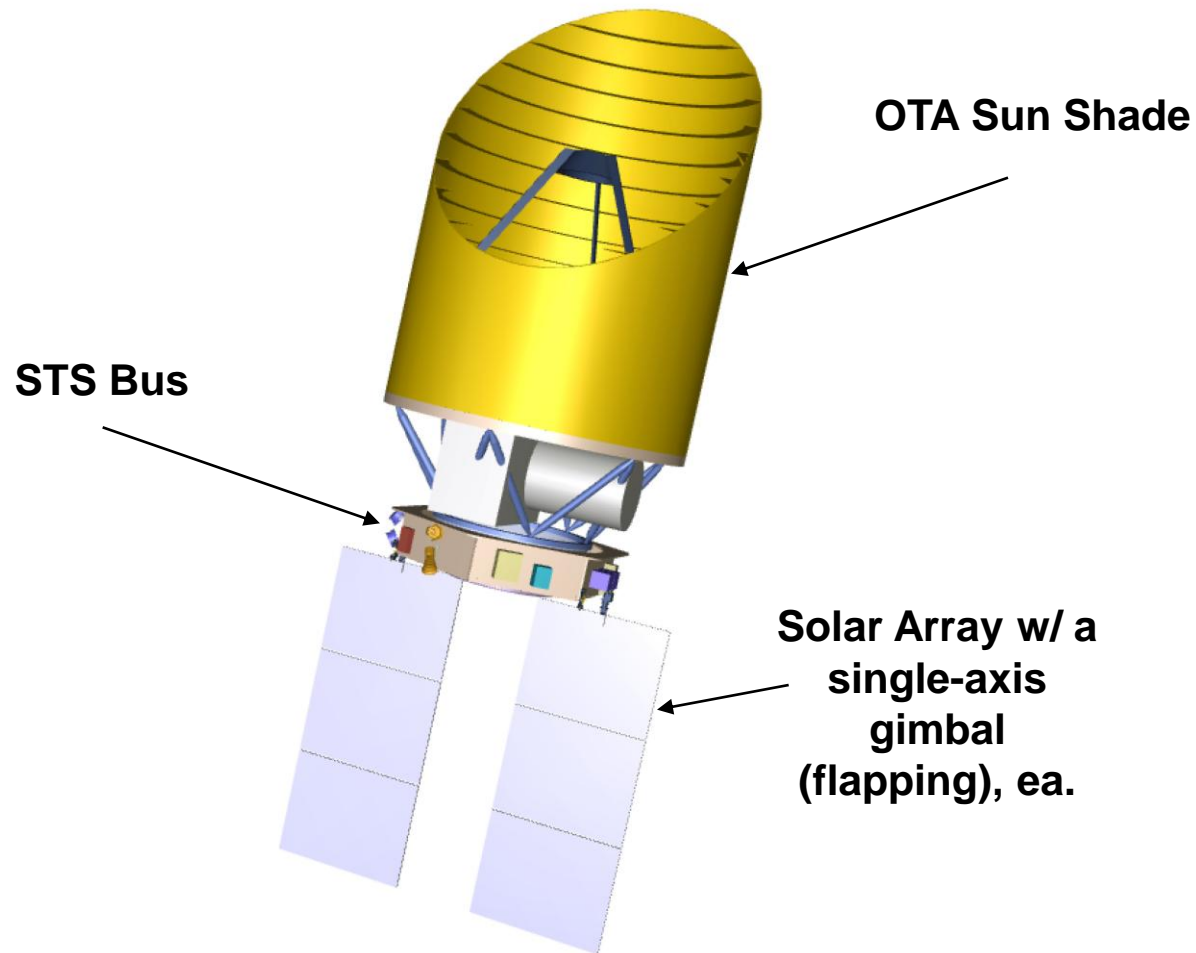




NWO-2 Science Telescope Spacecraft (STS)



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STS

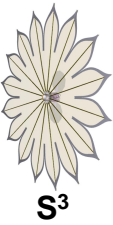
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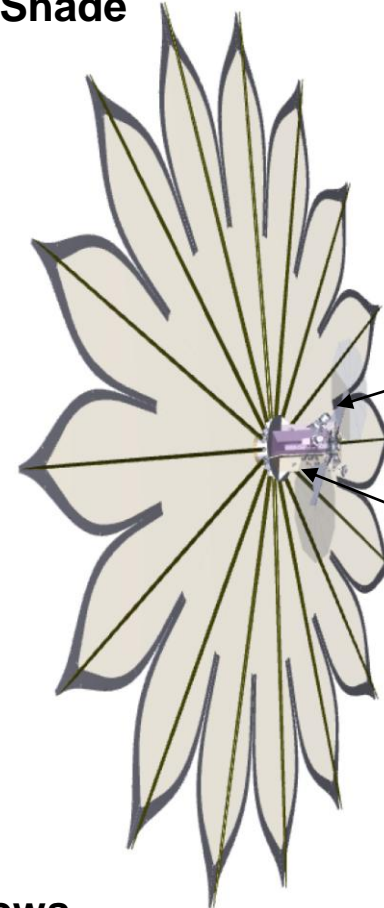
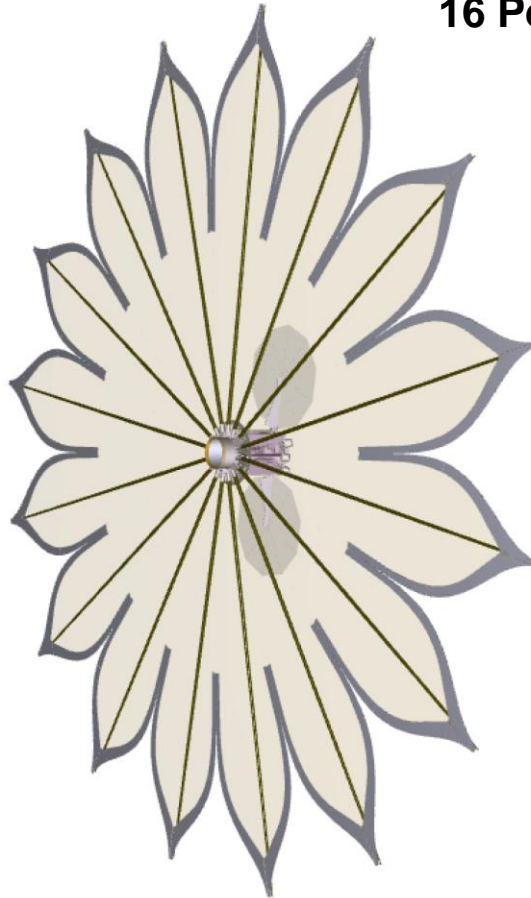


NWO-2 Star shade Spacecraft (S³)



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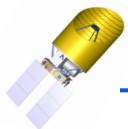
16 Petal Star Shade



Two Ultra-Flex Solar Arrays

S³ Bus

Isometric Views



STS

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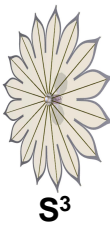
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STS Dry Mass Summation (Baseline)



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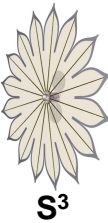
NWO-2 Science Telescope Spacecraft (STS)						
STS Payload						
	CBE Estimate (Kg)	% Total Dry Mass	Contingency	Allocation (Kg)		Ball Aero CBE Estimate
Optical Telescope Assembly (4-m)	2395	59%	30%	3114		2395
Exo Cam	161	4%	30%	209		161
Exo Spec	105	3%	30%	137		105
UV Instrument	95	2%	30%	124		95
GA WFC/ Guider	366	9%	30%	476		366
Shadow Sensor Assembly	49	1%	30%	64		49
Misc.	137	3%	30%	178		137
Payload Total	3308	81%	30%	4300		3308
STS Spacecraft Bus						
	CBE Estimate (Kg)	% Total Dry Mass	Contingency	Allocation (Kg)	TRL	
Mechanical	333	8%	30%	433	6	525
Attitude Control	52	1%	30%	67	8	38
Thermal	29	1%	30%	38	8	29
Propulsion	86	2%	30%	112	8	42
Power	100	2%	30%	130	8	95
Avionics	58	1%	30%	76	6	99
Communications	65	2%	30%	85	8	32
Spacecraft Harness	53	1%	30%	69	8	96
Bus Total	777	19%	30%	1010		956
STS Dry Mass						
	CBE Estimate (Kg)	% Total Dry Mass	Contingency	Allocation (Kg)		
Science Payload Total	3308	81%	30%	4300		3308
Bus Total	777	19%	30%	1010		956
Spacecraft Dry Mass	4085	100%	30%	5310		4264

GSFC Gold Rules recommend $\geq 30\%$ Technical Resource Margin be allocated for mass at the end of Pre-Phase A (for typical robotic missions). In this case, 30% contingency is held against the spacecraft dry mass.





STS Wet & Launch Mass Summation (Baseline)



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STS Wet & Launch Mass					
	CBE Estimate (Kg)	% Total Wet Mass	Contingency	Allocation (Kg)	Ball Aero CBE Estimate
Spacecraft Dry Mass	4085	90%	30%	5310	
Propellant Mass	448	10%		448	327.6
Spacecraft Wet Mass	4533	100%	27%	5758	
Payload Adapter Fairing (PAF)	114		5%	120	
Separation System	49		5%	51	
Total Launch Mass	4696		26%	5930	4591

No additional propellant contingency is held here, because the propellant calculation is based on conservative ΔV values and the spacecraft mass with allocation.





NWO-2 STS Launch Vehicle Evaluation



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LAUNCH VEHICLE EVALUATION

Allocation (Kg)	Launch (Kg)	LV Perf Mass (Kg)	Launch Capability Used
Atlas V (551)	5930	6365	93.2%

LV Perf. Mass Atlas V (551) - Launch Mass **435.5 kg**

Gold Rule Margin Value* [Atlas V 551] 7.3%

The NWO-2 Science Telescope Spacecraft (STS) can be accommodated in the Atlas V (551) launch vehicle with positive margin.

Launch Energy, C3: $-0.5 \text{ km}^2/\text{s}^2$
Total Delta V ~ 192.4 m/s (includes margin)

*Margin (in percent) = (Available Resource - Estimated Value of Resource) / Estimated Resource X 100



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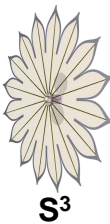
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Star shade Spacecraft Dry Mass Summation (Baseline)



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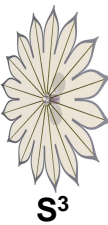
NWO-2 Starshade Spacecraft (S ³)						
Payload						
	CBE Estimate (Kg)	% Total Dry Mass	Contingency	Allocation (Kg)		NG CBE Estimate
Astrometric Sensor (AS)	80	3%	30%	104		79.9
Star Shade	1500	56%	30%	1950		1500
Payload Total	1580	59%	30%	2054		1580
Spacecraft Bus						
	CBE Estimate (Kg)	% Total Dry Mass	Contingency	Allocation (Kg)	TRL	
Mechanical (Inc's Ultra-flex SA's)	555	21%	30%	722	6	625
Attitude Control	57	2%	30%	74	8	75
Thermal	75	3%	30%	98	8	70
Propulsion	290	11%	30%	377	6	334
Power (Solar Array inc in Mech Sys)	28	1%	30%	37	8	149
Avionics	36	1%	30%	47	6	61
Communications	28	1%	30%	37	8	20
Spacecraft Harness	46	2%	30%	59	8	50
Bus Total	1115	41%	30%	1449		1382
Starshade Spacecraft Dry Mass						
	CBE Estimate (Kg)	% Total Dry Mass	Contingency	Allocation (Kg)		
Payload Total	1580	59%	30%	2054		1580
Bus Total	1115	41%	30%	1449		1382
Starshade S/C Dry Mass	2695	100%	30%	3503		2962

GSFC Gold Rules recommend $\geq 30\%$ Technical Resource Margin be allocated for mass at the end of Pre-Phase A (for typical robotic missions). In this case, 30% contingency is held against the spacecraft dry mass.





Star shade Spacecraft Wet & Launch Mass Summation (Baseline)



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Starshade Spacecraft Wet Mass					
	CBE Estimate (Kg)	% Total Wet Mass	Contingency	Allocation (Kg)	NG CBE Estimate
Starshade S/C Dry Mass	2695	61%	30%	3503	
Propellant Mass - Xenon	1220	28%		1220	1220
Propellant Mass - Biprop	476	418%		476	339
Starshade S/C Wet Mass	4391	89%	18%	5199	
Payload Adapter Fairing (PAF)	114		5%	120	
Separation System	49		5%	51	
Total Launch Mass	4554		18%	5371	4521

No additional propellant contingency is held here, because the propellant calculation is based on conservative ΔV values and the spacecraft mass with allocation.





NWO-2 Star Shade Spacecraft Launch Vehicle Evaluation



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LAUNCH VEHICLE EVALUATION			
Allocation (Kg)	Launch (Kg)	LV Perf Mass (Kg)	Launch Capability Used
Atlas V (551)	5371	6325	84.9%
LV Perf. Mass Atlas V (551) - Launch Mass		954.4 kg	
Gold Rule Margin Value* [Atlas V 551]		17.8%	

The NWO-2 Star shade Spacecraft (S³) can be accommodated in the Atlas V (551) launch vehicle with positive margin.

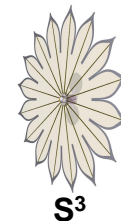
Launch Energy, C3: -0.5 km²/s²
Chemical Delta V ~ 339.4 m/s (includes margin)
Electrical Propulsion Delta V ~ 10,300 m/s (includes margin)

*Margin (in percent) = (Available Resource - Estimated Value of Resource) / Estimated Resource X 100





NWO-2 STS Power Modes (1 of 2)



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NWO-2 Power

	STS Payload											
	Launch Power (W)			Commission Power (W)			Science Ops Power (W)			Comm. Downlink Event Power (W)		
	Estimate	Cont.	Allocated		Cont.	Allocated	Estimate	Cont.	Allocated	Estimate	Cont.	Allocated
STS Payload System	565.0	30%	734.5	955.0	30%	1241.5	1090.0	30%	1417.0	1090.0	30%	1417.0
Total	565.0	30%	734.5	955.0	30%	1241.5	1090.0	30%	1417.0	1090.0	30%	1417.0

	STS Spacecraft Bus											
	Estimate	Cont.	Allocated	Estimate	Cont.	Allocated	Estimate	Cont.	Allocated	Estimate	Cont.	Allocated
Mechanical	0.0	30%	0.0	0.0	30%	0.0	0.0	30%	0.0	0.0	30%	0.0
ACS	30.0	30%	39.0	4.3	30%	5.6	4.3	30%	5.6	5.3	30%	6.9
Thermal	20.0	30%	26.0	30.0	30%	39.0	40.0	30%	52.0	30.0	30%	39.0
Propulsion	3.0	30%	3.9	3.0	30%	3.9	3.0	30%	3.9	3.0	30%	3.9
C&DH	38.0	30%	49.4	380.0	30%	494.0	380.0	30%	494.0	380.0	30%	494.0
RF Comm	0.0	30%	0.0	81.0	30%	105.3	81.0	30%	105.3	121.0	30%	157.3
Power System	46.5	30%	60.5	116.1	30%	150.9	140.4	30%	182.5	124.8	30%	162.2
Total	137.5	30%	178.8	614.4	30%	798.7	648.7	30%	843.3	664.1	30%	863.3

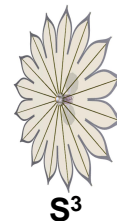
Totals (W)	702.5	30%	913.3	1569.4	30%	2040.2	1738.7	30%	2260.3	1754.1	30%	2280.3
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NOTE: A contingency of 30% is applied throughout.





NWO-2 STS Power Modes (2 of 2)



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	NWO-2 Power
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	STS Payload								
	Comm. Cross-link Event Power (W)			Safehold Power (W)			Peak Power (W)		
	Estimate	Cont.	Allocated	Estimate	Cont.	Allocated	Estimate	Cont.	Allocated
STS Payload System	400.0	30%	520.0	565.0	30%	734.5	1270.0	30%	1651.0
Total	400.0	30%	520.0	565.0	30%	734.5	1270.0	30%	1651.0

	STS Spacecraft Bus								
Mechanical	0.0	30%	0.0	0.0	30%	0.0	0.0	30%	0.0
ACS	4.3	30%	5.6	5.3	30%	6.9	4.3	30%	5.6
Thermal	30.0	30%	39.0	30.0	30%	39.0	75.0	30%	97.5
Propulsion	3.0	30%	3.9	3.0	30%	3.9	3.0	30%	3.9
C&DH	380.0	30%	494.0	380.0	30%	494.0	38.0	30%	49.4
RF Comm	307.0	30%	399.1	0.0	30%	0.0	64.0	30%	83.2
Power System	124.3	30%	161.6	55.5	30%	72.2	158.4	30%	205.9
Total	848.6	30%	1103.2	473.8	30%	615.9	342.7	30%	445.5

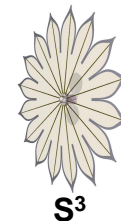
Totals (W)	1248.6	30%	1623.2	1038.8	30%	1350.4	1612.7	30%	2096.5
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NOTE: A contingency of 30% is applied throughout.





NWO-2 Star shade Spacecraft (S³) Power Modes (1 of 2)



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	S ³ Payload											
	Launch Power (W)			Commission Power (W)			Science Ops Power (W)			Retargeting Event Power (W)		
	Estimate	Cont.	Allocated	Estimate	Cont.	Allocated	Estimate	Cont.	Allocated	Estimate	Cont.	Allocated
Starshade Payload System	0.0	30%	0.0	73.0	30%	94.9	73.0	30%	94.9	73.0	30%	94.9
Total	0.0	#DIV/0!	0.0	73.0	30%	94.9	73.0	30%	94.9	73.0	30%	94.9

	S ³ Spacecraft Bus											
	Estimate	Cont.	Allocated	Estimate	Cont.	Allocated	Estimate	Cont.	Allocated	Estimate	Cont.	Allocated
Mechanical	0.0	30%	0.0	0.0	30%	0.0	0.0	30%	0.0	0.0	30%	0.0
ACS	22.0	30%	28.6	36.3	30%	47.2	36.3	30%	47.2	37.3	30%	48.5
Thermal	0.0	30%	0.0	100.0	30%	130.0	60.0	30%	78.0	60.0	30%	78.0
Propulsion	6.0	30%	7.8	6.0	30%	7.8	6.0	30%	7.8	14661.0	10%	16127.1
C&DH	55.0	30%	71.5	74.0	30%	96.2	74.0	30%	96.2	74.0	30%	96.2
RF Comm	0.0	30%	0.0	16.0	30%	20.8	41.0	30%	53.3	41.0	30%	53.3
Power System	10.1	30%	13.1	50.6	30%	65.8	50.6	30%	65.8	50.6	30%	65.8
Total	93.1	30%	121.0	282.9	30%	367.8	267.9	30%	348.3	14923.9	10%	16468.9

Totals (W)	93.1	30%	121.0	355.9	30%	462.7	340.9	30%	443.2	14996.9	10%	16563.8
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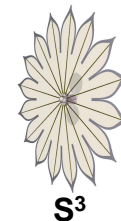
NOTE:

- (1) A contingency of 30% is generally applied to the power values except for the Electric Propulsion system, which is 10% (a value suggested by GRC).
- (2) The Solar Arrays are sized such that the needed power is available at the end-of-life. Solar Array degradation must be considered in determining its size.





NWO-2 Star shade Spacecraft (S³) Power Modes (2 of 2)



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	S ³ Payload											
	Comm. Downlink Event Power (W)			Comm. Cross-link Event Power			Safehold Power (W)			Peak Power (W)		
	Estimate	Cont.	Allocated	Estimate	Cont.	Allocated	Estimate	Cont.	Allocated	Estimate	Cont.	Allocated
Starshade Payload System	54.0	30%	70.2	7.0	30%	9.1	21.9	30%	28.5	112.0	30%	145.6
Total	54.0	30%	70.2	7.0	30%	9.1	21.9	30%	28.5	112.0	30%	145.6

	S ³ Spacecraft Bus											
	Estimate	Cont.	Allocated	Estimate	Cont.	Allocated	Estimate	Cont.	Allocated	Estimate	Cont.	Allocated
Mechanical	0.0	30%	0.0	0.0	30%	0.0	0.0	30%	0.0	0.0	30%	0.0
ACS	36.3	30%	47.2	37.3	30%	48.5	36.3	30%	47.2	424.3	30%	551.6
Thermal	100.0	30%	130.0	100.0	30%	130.0	175.0	30%	227.5	200.0	30%	260.0
Propulsion	6.0	30%	7.8	6.0	30%	7.8	6.0	30%	7.8	14661.0	30%	19059.3
C&DH	74.0	30%	96.2	74.0	30%	96.2	55.0	30%	71.5	254.0	30%	330.2
RF Comm	241.0	30%	313.3	0.0	30%	0.0	16.0	30%	20.8	251.0	30%	326.3
Power System	50.6	30%	65.8	50.6	30%	65.8	10.1	30%	13.1	88.1	30%	114.5
Total	507.9	30%	660.3	267.9	30%	348.3	298.4	30%	387.9	15878.4	30%	20641.9

Totals (W)	561.9	30%	730.5	274.9	30%	357.4	320.3	30%	416.4	15990.4	30%	20787.5
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NOTE:

- (1) A contingency of 30% is generally applied to the power values except for the Electric Propulsion system, which is 10% (a value suggested by GRC).
- (2) The Solar Arrays are sized such that the needed power is available at the end-of-life. Solar Array degradation must be considered in determining its size.





NWO-2 Cost Information



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- **Provide selected estimated cost information in 2008 Constant Year dollars (to be provided at a later date):**
 - Parametric cost estimate of the spacecraft buses (STS and S³)
 - Grassroots cost estimates for the following:
 - Spacecraft buses (STS and S³)
 - Spacecraft bus and Observatory level I&T and Environmental testing for each spacecraft
 - Mission Operations
 - Science and instrument data processing are not included
 - Flight Software costs
 - Covered Grassroots cost mission periods includes Phases A through E/F
 - Provide Grassroots Mission Level Project Management, Systems Engineering, etc. ROM values. Will require payload cost estimates from customer team.
 - ROM Launch Vehicle cost



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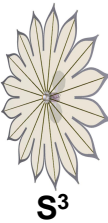
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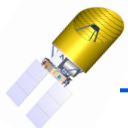


Comments and Recommendations



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- The “Grassroots” top-level design and initial costs have the level of fidelity in accordance with a four a half day study, i.e., we have done the best we can within the time provided.
- The MDL has not sought to fully optimize the design, rather, to evaluate the STS (Ball Aerospace) and S³ (Northrop Grumman) top-level designs to demonstrate the proof-of-concept and to provide a cost estimate. For typical missions design optimization would be pursued as the design matures.
- We have assumed a 30% mass contingency for the payload and the spacecraft bus. However; any new technology, or low Technology Readiness Level (TRL) items, will likely require larger contingencies, perhaps up to 50%.
- There is no specific rule or guideline regarding the launch vehicle margin value, but a positive value about 5% to 10% or more should be a target.



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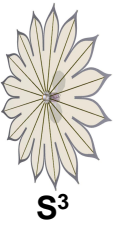
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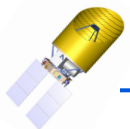


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Back Up Slides



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NWO-2 Supporting Data



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- **Supporting spreadsheets / tools**
 - Mission summary/Includes MEL*: “NWO-2_System_Sheets.xls”
- **Useful web sites**
 - Access to Space
 - <http://idcwebdev.gsfc.nasa.gov:8082/> provides launch vehicle performance information and other useful design data.
 - Rapid Spacecraft Development Office
 - <http://rsdo.gsfc.nasa.gov/> provides spacecraft bus studies and procurement services.
 - Space Environment Information System – SPENVIS
 - <http://www.spennis.oma.be/spennis/>
 - ELV Launch Vehicle Performance Tool
 - <http://elvperf.ksc.nasa.gov/>, <http://www.osc.com>
 - Gold Rules
 - <http://mesa.gsfc.nasa.gov>
 - NASA Online Directives Information System (NODIS):
 - http://nodis.hq.nasa.gov/main_lib.html
 - Goddard Directives Management System (GDMS):
 - <http://gdms.gsfc.nasa.gov/gdmsnew/home.jsp>



Note: *MEL – Master Equipment List

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Power Modes



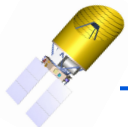
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1. Science Telescope S/C

- **Launch Power:**
 - Instruments Pwr off
 - S/C Bus: Low Pwr
- **Commission Pwr:**
 - Instr Commiss Pwr On
 - S/C Pwr On
- **Science Ops Pwr:**
 - Instr Pwr On
 - S/C Pwr On
- **Comm Dwn Link Event:**
 - Instr Pwr On
 - S/C Pwr On
 - Comm. Transmitters On
- **Comm Cross Link Event:**
 - Instr Pwr On
 - S/C Pwr On
 - Comm. Transmitters On
- **Safehold:**
 - Instr. low Pwr
 - S/C Pwr on
- **Peak Pwr**

2. Star Shade S/C (S³)

- **Launch Power:**
 - Payload Pwr off
 - S/C Bus: Low Pwr
- **Commission Pwr:**
 - Payload Pwr On
 - S/C Pwr On
- **Science Ops Pwr:**
 - Payload Pwr On
 - S/C Pwr On
- **Retargeting Pwr:**
 - Payload Pwr On
 - S/C Pwr On
 - SEP Pwr On
- **Comm Dwn Link Event:**
 - Payload Pwr On
 - S/C Pwr On
 - Comm. Transmitters On
- **Comm Cross Link Event:**
 - Payload Pwr On
 - S/C Pwr On
 - Comm. Transmitters On
- **Survival:**
 - Payload Pwr off
 - S/C Pwr On
 - SEP Pwr off
- **Peak Pwr**



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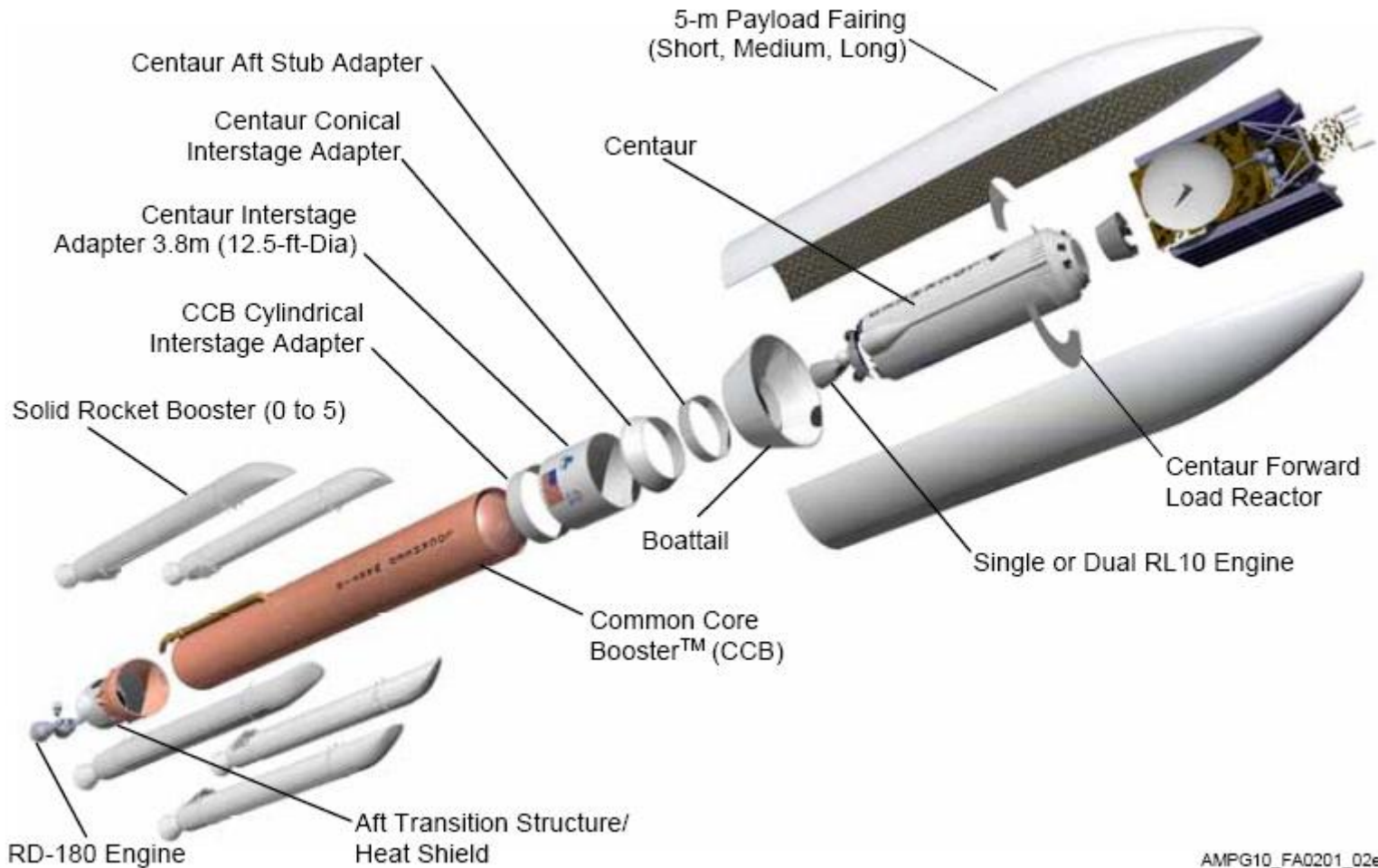
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Atlas V (500)

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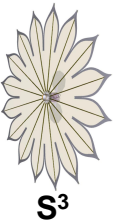
Figure A.2.1-2: Atlas V 500 Series Launch Vehicle



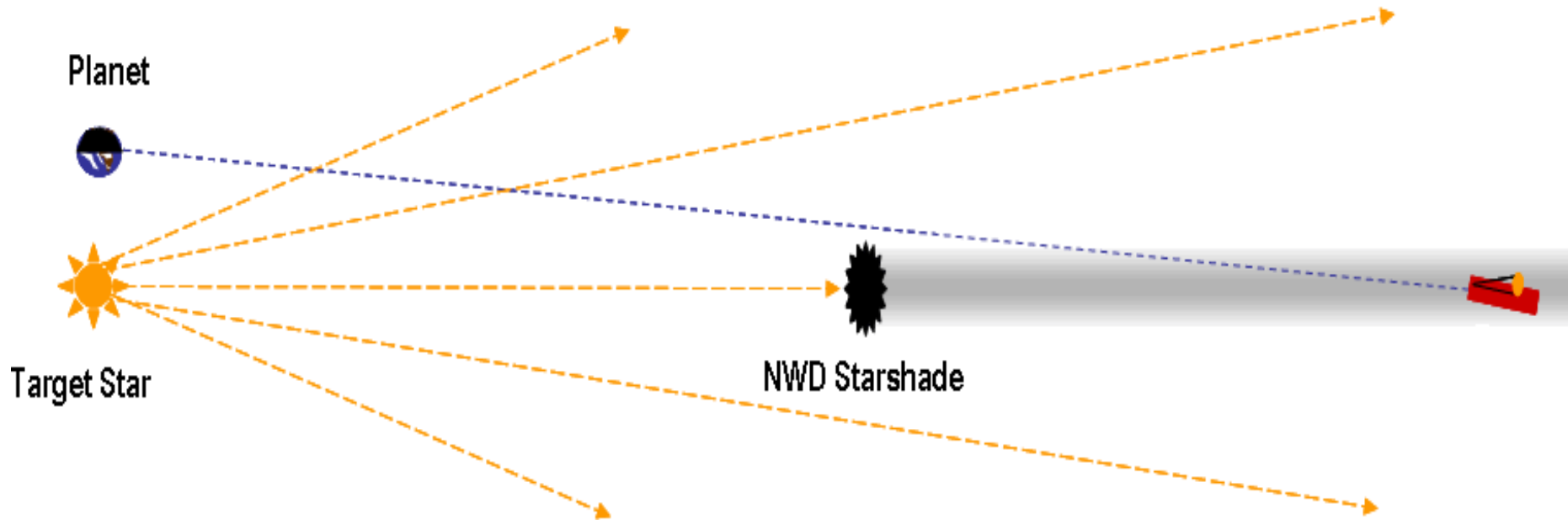
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New Worlds Observer



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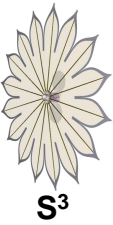
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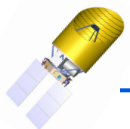
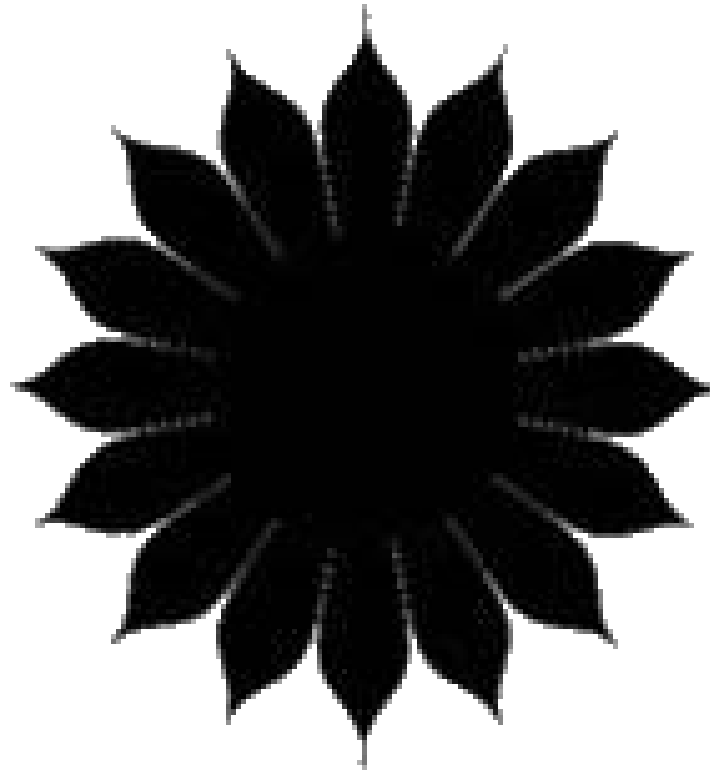




16 Petal Star shade



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