NEW WORLDS OBSERVER
OPERATIONS CONCEPT (OPSCON)

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1.0 MISSION OVERVIEW

1.1 NWO SCOPE

The New Worlds Observer mission aims to discover and analyze terrestrial extrasolar planets in the following way:

1) Detection: First, using the space telescope and StarShade, NWO will survey nearby stars to search for exoplanets; both terrestrial and giant planets can be found by this system.
2) System Mapping: Following detection of an exoplanet, NWO will map the discovered system by taking a series of images that will allow it to measure the planet's orbit, brightness, and colors. This will give us information about the basic nature of each planet.
3) Planet Studies: A detailed study of the individual planets will take place by taking spectra and more detailed photometry of each planet. Spectroscopy allows NWO to analyze the chemical composition of planets' atmospheres and surfaces. Detailed photometry will show variation in color and intensity as surface features rotate in and out of the field of view, allowing for the detection of oceans, continents, polar caps, and clouds.

In addition to finding and analyzing terrestrial planets, NWO can discover and analyze gas giants, exo-zodiacal dust, debris disks, etc. in the same systems as the terrestrial planets. NWO will also be capable of providing high quality, general astrophysics observations.

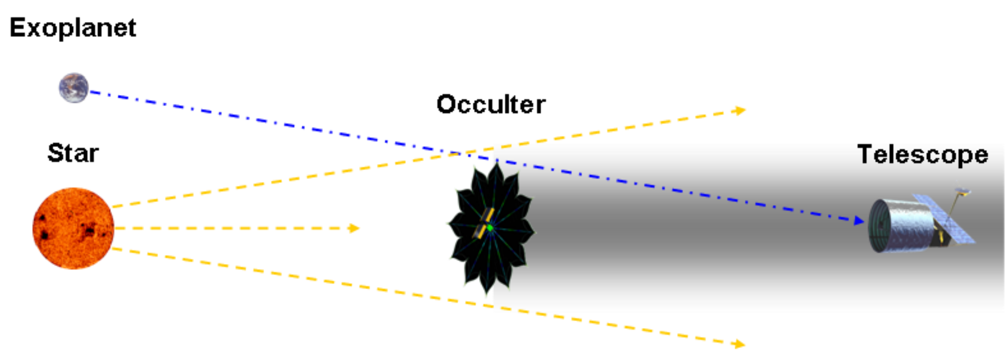

Figure 1-1: NWO Overview

2.0 SYSTEM OVERVIEW

This section provides a description of the NWO system scope, architecture, configuration, constraints, and interfaces.

2.1 SYSTEM CONSTITUENTS

The NWO system comprises the following segments and elements, with interrelationships depicted in the figure below:

1) First of the two NWO Spacecraft is the Starshade Spacecraft, which is composed of the Spacecraft Bus, the 50 meter Starshade Payload and an Astrometric Sensor.
2) The second Spacecraft is the Science Telescope, which is composed of the Spacecraft Bus, the Science Instruments, the Optical Telescope Element, and the Shadow Sensor.
3) The Ground Segment is composed of the Science Operations Center (SOC), the Mission Operations Center (MOC), the Flight Dynamics Facility (FDF) and the Deep Space Network (DSN)..
   a) The SOC and the (MOC) are co-located at Space Telescope Science Institute (STScI).
4) The Launch Segment is composed of the Launch Vehicle, Payload Adapter, and Launch Site Services.

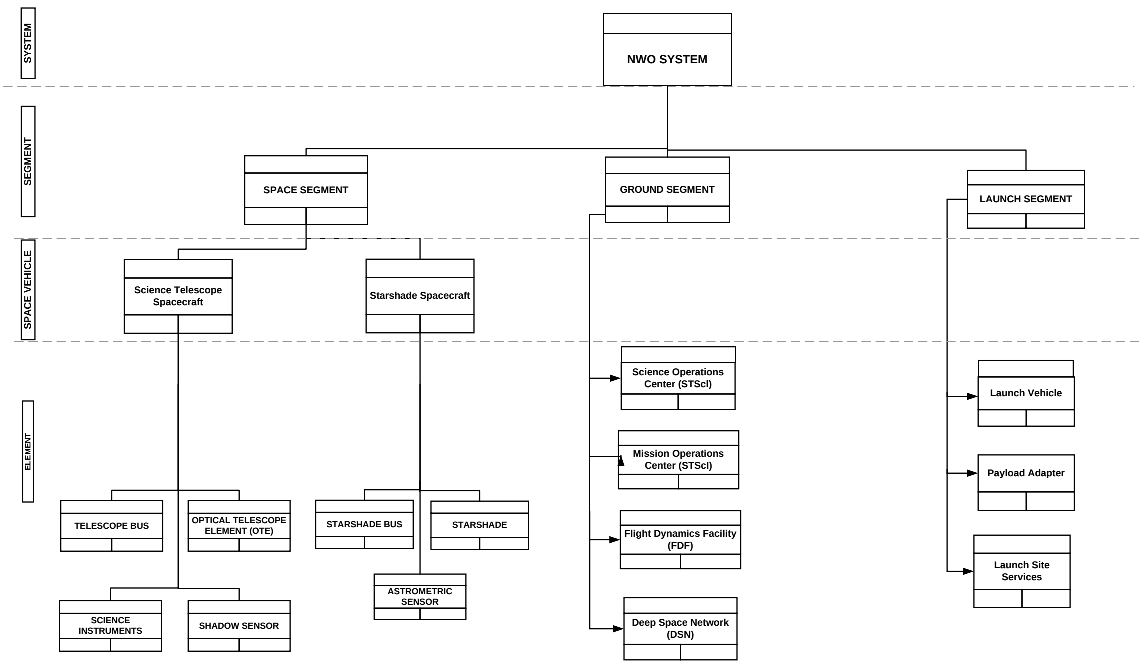

Figure 2-1: The NWO System Constituents

2.2 OPERATIONS DRIVERS

NWO has several features that drive the operations concept and the mission architecture. The coordinated operation of the two separate spacecraft to perform the exoplanet observations is the most significant driver; a detailed scenario describing how the exoplanet observation is accomplished is provided as an appendix to this ops concept. The coordinated operation requires a single operations team to operate the two spacecraft as a single instrument for exoplanet observations. Each spacecraft will have its own operations team at launch; these teams will be consolidated into a single team during the exoplanet observation commissioning phase.

NWO has the potential to downlink large volumes of data - up to 2.5 Tbits per day. This drove the architecture to include the DSN Ka-band capability, which can receive data at rates up to 150 Mbps.

The exoplanet observations have a number of points in the alignment and observation process that require ground system involvement, particularly early in the mission. The DSN is not a flexible network; therefore, an additional network of ground station is included which can be scheduled with less lead.

The need for timely evaluation of alignment and exoplanet observations also drives the operations to be staffed around the clock.

The general astrophysics phase of the mission is expected to be similar to HST and JWST. The science operations for NWO are located at the STScI, which is eminently capable of supporting a world class space observatory. Because of the tight connection between science and mission operations, the mission operations are also located at the STScI.

2.3 SYSTEM FUNCTIONAL ARCHITECTURE

This section provides a description of the NWO system scope, architecture, configuration, constraints, and interfaces with the NWO users.

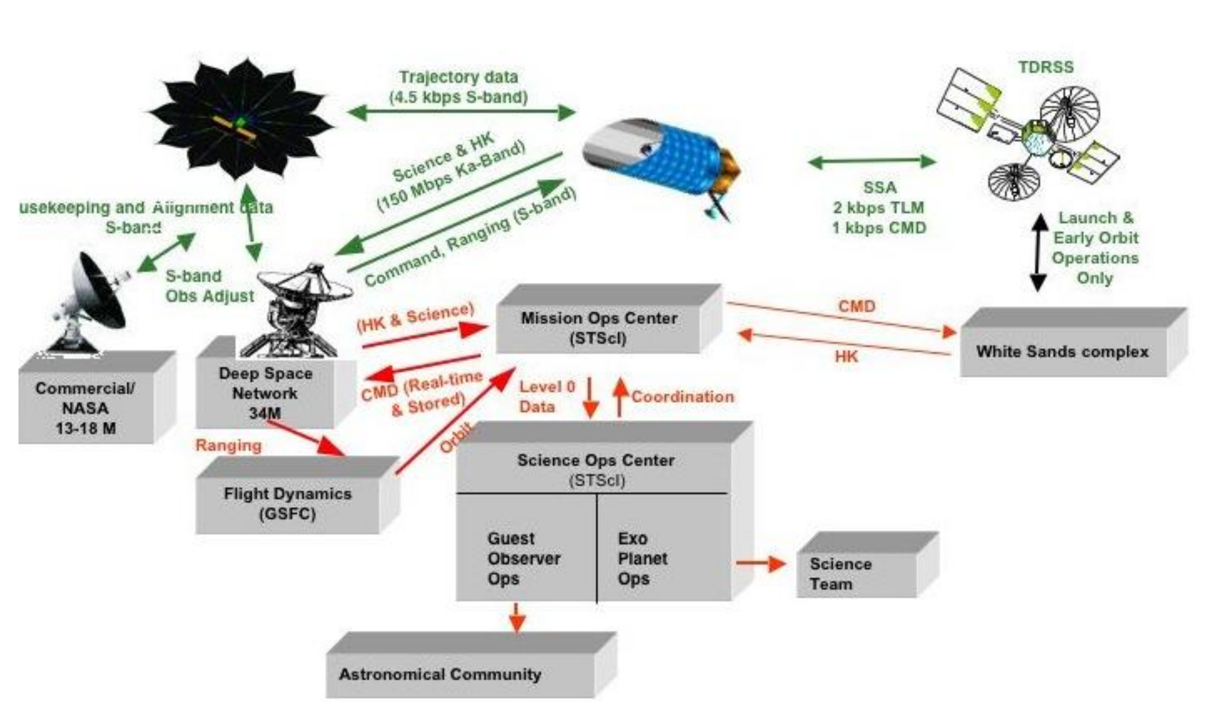

Figure 5-1: NWO End-to-end Block Diagram

2.3.1 COMMUNICATIONS ARCHITECTURE

The Telescope instruments are capable of generating large volumes of data – up to 2.5 Tbits per day during general astrophysics observations. This data is downlinked once per day to the DSN, using Ka-band and a downlink rate of 150 Mbps. The Starshade generates much less data – a few Gbits per day consisting of housekeeping data and astrometric data from JMAPS. The Starshade has one DSN contact day for data downlink and for tracking. The Starshade link uses S-band, with a data rate of 1 Mbps.

The two spacecraft communicate with each other. During the slew to a new target, the StarShade communicates with the telescope once per day to measure the interspacecraft range (and possibly bearing). During the trajectory and alignment for exoplanet observations and throughout the observation, the two spacecraft are in continuous contact to establish and maintain the alignment. The Starshade sends its telemetry to the Telescope during the observation for downlink to the ground.

Setting up the exoplanet observations and monitoring the alignment requires additional ground station contacts, especially early in the science phase, before routine operations have been established. Existing commercial and NASA ground stations will be used for these contacts because they will be easier to schedule than the DSN and are capable of supporting the low rate commands and telemetry needed for these contacts.

TDRSS will be used at launch to provide critical event coverage from separation until the spacecraft are high enough to have continuous DSN coverage.

NWO provides coverage for all critical events so that NASA has detailed engineering data associated with any on-orbit activity where the risk of failure is higher than normal. For both the telescope and the StarShade, the critical events include separation from the launch vehicle, attitude acquisition, solar array deployment, and chemical thruster checkout. The telescope orbital maneuvers are critical events. For the StarShade, the StarShade deployment and the SEP thruster checkout are critical events. The DSN is used for all critical event coverage except for those that occur immediately after launch vehicle separation; those are covered by TDRSS.

The Telescope Report includes larger data volumes than 2.5 Tbits – up to 3.7 Tbits, mostly from the Wide Field Camera. This appendix assumes that the data volume will be less than this maximum because the Wide Fields camera will not be used all of the time and the data can be edited or subsetted for some observations. In the event that this data volume is required, it could be accommodated by extending the daily DSN contact from 5 hours to 8 hours.

Optical communications may also be an option in the NWO timeframe. An optical comm. demonstration mission will be part of the LADEE mission to the moon in 2012, with a downlink bandwidth of 622 Mbps. Additional demonstrations are planned, including one on JDEM, and L2 mission that launches in 2016.

2.3.2 GROUND ELEMENTS

This section describes the functions of the ground segment elements.

2.3.2.1 DSN

The Deep Space Network provides communications to both spacecraft once per day during normal operations. NWO uses the 34 meter antennas. The DSN is scheduled months in advance.

We have discussed the NWO requirements and operations concept with the DSN Future Planning office. NWO uses capabilities expected to be in place well before the launch date.

2.3.2.2 Other Ground Stations

Smaller ground stations will be used to augment the DSN for the establishment and monitoring of the exoplanet observation alignment and to monitor the Starshade maneuvers as it moves from one target to the next. These antennas will be from 11 to 18 meters. These stations provide low rate S—band communications for commands and telemetry, and require less lead time to schedule than the DSN

2.3.2.3 Mission Operations Center

The Mission Operations Center is colocated with the SOC at the STScI. It is responsible for the operations of both spacecraft. The MOC performs the following functions:

a. DSN and other ground station scheduling
b. Command load generation and constraint checking
c. Command transmission via DSN and other ground stations
d. Observatory health and safety monitoring
e. Data accounting
f. Spacecraft subsystem performance evaluation
g. Level zero processing

The MOC will be staffed around the clock due to the need for frequent monitoring of the StarShade slews and the alignment of the two spacecraft for exoplanet observations. Staffing may be reduced later in the mission if the team is confident that these operations can be safely and successfully performed autonomously.

2.3.2.4 Science Operations Center

The Science Operations Center plans the science observations, processes the data, archives it, and distributes it to the science users. The STScI serves both the NWO science team and the general astrophysics community.

The SOC will define the plan of the sequence of exoplanet targets before launch. This plan will be updated to incorporate new discoveries and to accommodate the adjustments to the exoplanet observations. Exoplanet observations will be set up with a nominal timeline but this timeline will usually be adjusted based on the initial observations. A few observations may be cut short, but others will be extended to perform exoplanet characterization.

This fluid schedule is not particularly compatible with the DSN, which requires scheduling months in advance. The DSN schedule will be set and the slews to targets will be scheduled so that the initial exoplanet observation will be complete at the time of one of the two daily DSN contacts (one for the telescope and one for the StarShade). The smaller, more flexible S-band stations will augment the DSN, allowing the ground to monitor and adjust the alignment of the two spacecraft. These stations are scheduled a few weeks in advance, and will be rescheduled as required by changes that occur on shorter time scales.

The project scientist and the science team will establish the priorities among the exoplanet and general astrophysics objectives and the operations team will use these priorities in scheduling the activities of the two spacecraft. The general astrophysics observations will need to be flexible, since they may not happen at their nominal time due to changes in the exoplanet observations. The general astrophysics observations should be event driven rather than absolute time driven, so that they can be shifted in time without requiring a significant rescheduling effort. Observations should not be selected if the targets are near the edge of the field of regard. In addition, if the observations are coordinated with those of other observatories, the other observatories will need the flexibility to adapt to shifts in the NWO schedules.

Like the MOC, the SOC will be staffed around the clock, at least in the initial phases of the science operations.

2.3.2.5 Flight Dynamics

The flight dynamics functions include orbit determination, orbit data product generation, and maneuver planning. The flight dynamics functions will include tools that will be used to predict and evaluate the performance of the trajectory and alignment control. These tools will be used during the commissioning and possibly in the early part of the science mission phase.

2.4 COMMUNICATIONS ARCHITECTURE

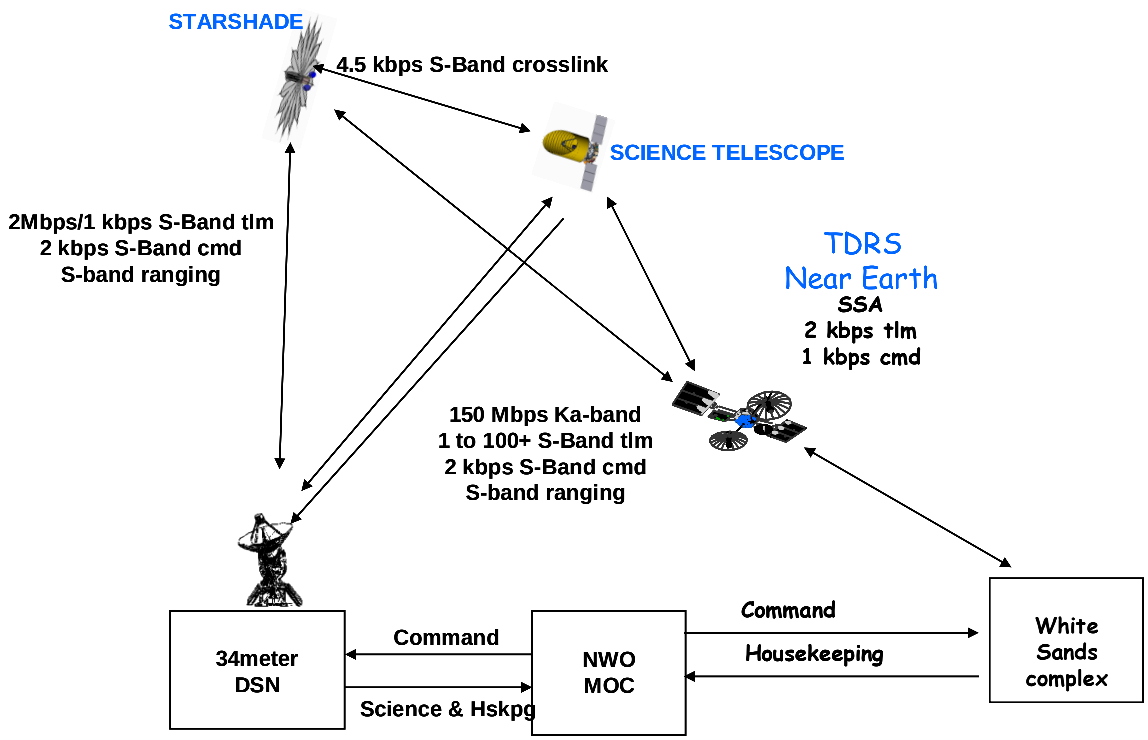

Figure 2.3 System Communications Architecture

2.5 MISSION TIMELINE

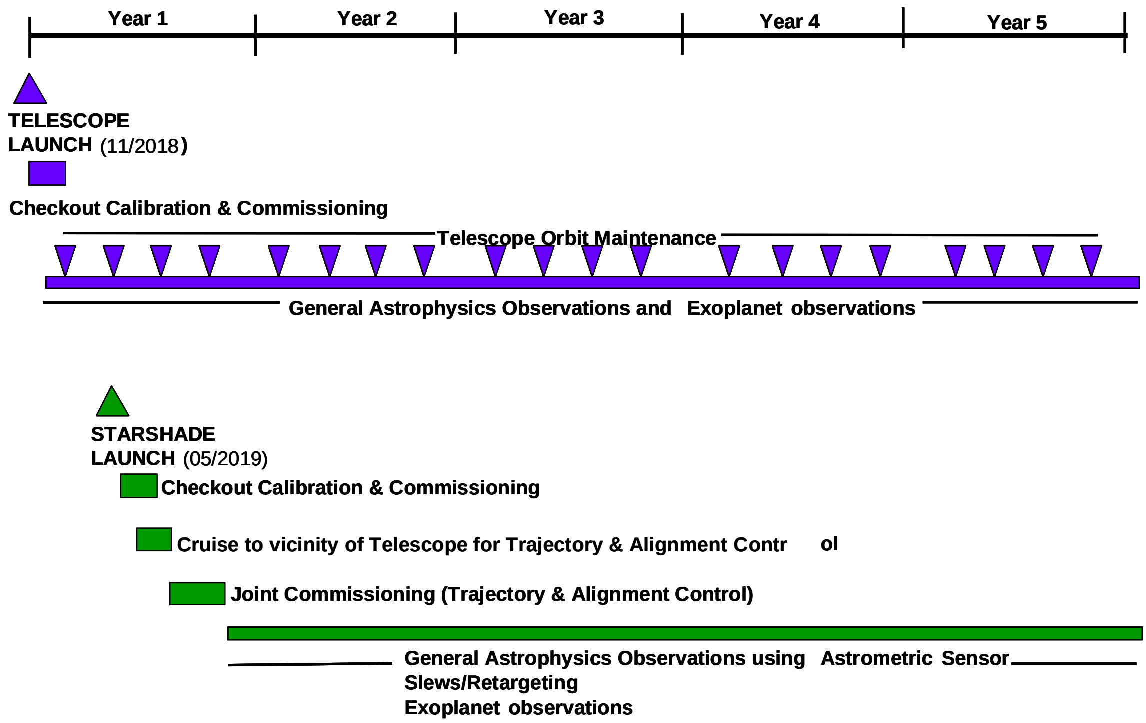

Figure 2.4 Mission Timeline

The StarShade is launched 6 months after the telescope. The StarShade takes about 120 days to get to L2, and we have allocated 30 days to move it into the appropriate position relative to the telescope. Once in position, another 30 days are allocated to commissioning the two systems to work together. Normal operations will then commence and last for at least 5 years.

Figure 2-2 shows a timeline of a month in normal operations.

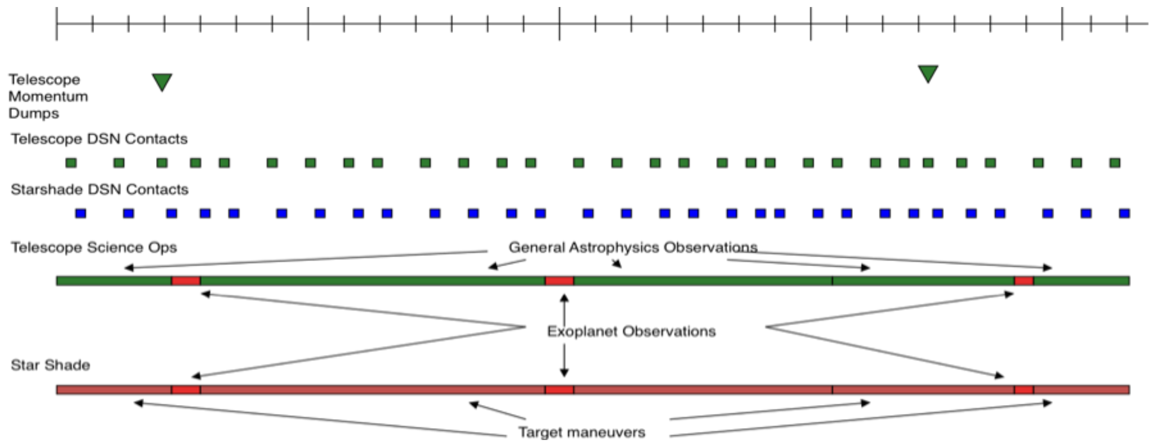

Figure 2-2: NWO Monthly Timeline

The telescope momentum dumps are three weeks apart so that there is time to collect enough tracking data to determine the orbit. The Starshade dumps its momentum whenever it is using one of its propulsion systems. The Starshade is not in a single orbit because of its frequent maneuvering.

Both the telescope and the StarShade have one contact per day. The telescope contact is 5 hours, sized to download up to 2.5 Tbits per day. The StarShade contact is 1 hour. The time between contacts will vary due to which station is used and the schedules of other users. NWO will use stations both in the Northern and Southern hemispheres to improve the orbit determination.

The exoplanet observations will be between 5 and 14 days apart. The duration of the exoplanet observation will typically be a day or two, but can vary from a few hours to up to two week.

3.0 MISSION PHASES

Mission phases are programmatic in nature and describe a period of time in the life of the NWO Spacecraft. The following defines the mission phases of the NWO Spacecraft:

- Pre-Launch
- Launch
- Deployment, Checkout, and Trajectory Correction (DC&TC)
- Exoplanet Observation Commissioning (EOC)
- Science Operations
  - General Astrophysics
  - Exoplanet

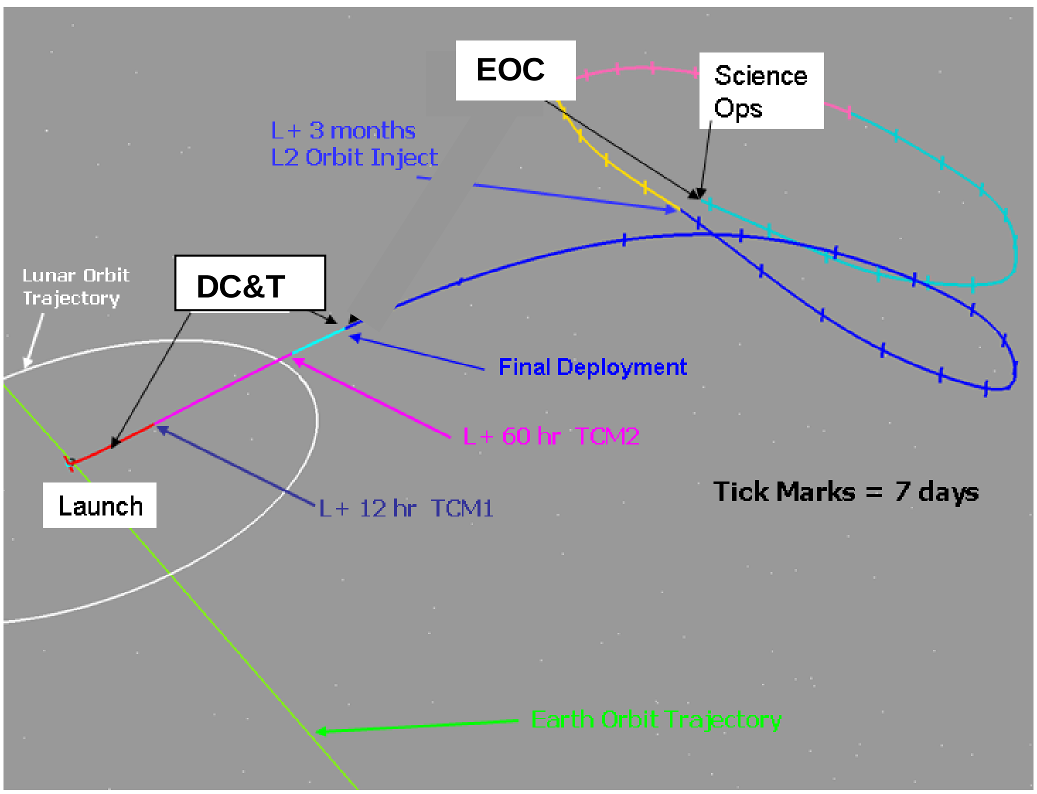

Figure 3-1: NWO Trajectory to L_2

3.1 PRE-LAUNCH

The Pre-launch phase and related operations begins with approval to ship the NWO Spacecraft to the launch site. This phase includes Spacecraft shipping preparations and transportation, its integration to the Launch Vehicle and upper stage, functional testing and checkout of the Space and Ground Segments of NWO at the launch site and ends with the start of the final countdown for the actual liftoff of the Spacecraft.

3.2 LAUNCH

Launch operations begin at the start of the final countdown for actual liftoff, continues through initiation of Spacecraft low rate communications, and ends after Spacecraft separation from the Launch Vehicle. Assumption is that each of the two spacecraft is launched in a separate launch vehicle six months apart, although trades involving a single launch vehicle are being examined.

3.3 DEPLOYMENT, CHECKOUT, AND TRAJECTORY CORRECTION (DC&TC)

The DC&TC phase begins immediately after separation from the upper stage and ends with the Science Telescope or Starshade deployed. All mid-course correction burns take place during this phase. Initial C3, departure Right Ascension and departure Declination control the outgoing trajectory and arrival parameters at the L2 injection point

- Telescope Spacecraft bus appendage deployments – Solar arrays, radiator shades, and high gain antenna.
- Starshade Spacecraft deployments – Solar arrays, Once the Spacecraft has been stabilized and orientated correctly, the StarShade will be deployed.
- Mid-Course Correction #1, and any subsequent corrections are required during this mission phase.

3.4 EXOPLANET OBSERVATION COMMISSIONING (EOC)

When the StarShade arrives within the vicinity of the telescope, we perform the commissioning of the trajectory alignment and control requires for exoplanet observations. Commissioning (completed 6 months (TBD) after StarShade launch) includes telescope, Starshade, and spacecraft, and mission-level operations.

3.5 SCIENCE OPERATIONS

This phase consists of two sub-phases: General Astrophysics and Exoplanet. The General Astrophysics sub-phase begins when the Telescope checkout is complete. This phase may begin prior to the telescope arrival at the L2 orbit. The Exoplanet sub-phase occurs after Exoplanet Observation Commissioning. Nominally, the Spacecraft executes the on-board observation plan and periodic Ground Segment contacts take place to upload the observation plan, determine the Spacecraft orbit, and download science and engineering data. This phase lasts at least 5 years (TBR) with a 10 year goal. Opscon Scenario, OS5 contains details about the science operations.

- Science Ops 1: General Astrophysics Phase:
  - Science Telescope and Starshade operating independently
- Science Ops 2: Exoplanet Phase:
  - Science Telescope and Starshade operating together

4.0 SPACECRAFT MODES

4.1 TELESCOPE MODES

The Telescope Spacecraft modes (Normal and Contingency) are defined as the following:

- Telescope Launch
- Telescope Wheel Attitude Maneuver
- Telescope Acquisition Without Starshade
- Telescope Science Ops Without Starshade
- Telescope Alignment With Starshade
- Telescope Science Ops With Starshade
- Thruster Firing
- Telescope Safe Hold
- Telescope Survival

4.1.1 TELESCOPE LAUNCH

- The attitude control subsystem is in standby mode.
- Coarse sun sensors, fine sun sensors and inertial reference unit (IRU) are enabled.
- Sensor data is processed but actuator commands are not allowed.

The Telescope is in Launch Mode when attached to the Launch Vehicle. This covers pre-launch and launch phases of the mission, up to separation from the Launch Vehicle. All appendages are stowed. Thrusters and ordnance are disabled.

The Spacecraft will not perform attitude control or active thermal control. Spacecraft telemetry will be available for Ground monitoring of Spacecraft health once transmitters are turned on. Spacecraft attitude control sensor data processing will be performed to allow Ground monitoring.

The Spacecraft will monitor status of payload fairing jettison and Telescope separation from the Launch Vehicle. After payload fairing jettison, telemetry transmitters will be turned on. Once the Spacecraft detects Launch Vehicle separation, autonomous transition to Deployment Mode will occur in preparation for solar array deployment.

Launch Mode is used during nominal and contingency operations. After transition to Deployment mode following separation from the Launch Vehicle, this mode will never be entered again.

4.1.2 TELESCOPE WHEEL ATTITUDE MANEUVER

- This mode is used to slew the Telescope to a new target.
- This mode can also be used to slew the Telescope during the D&TC phase and the CCC phase.
- Sensors and actuators include IRU, RWA, and HGA Drive.

4.1.3 TELESCOPE ACQUISITION WITHOUT STARSHADE

- This mode is used during the General Astrophysics science phase when the telescope is not observing, e.g. while it is acquiring a new target.

4.1.4 TELESCOPE SCIENCE OPS WITHOUT STARSHADE

- This mode is invoked during the General Astrophysics Science phase.
- Telescope is observing and is not in contact with the Starshade.

4.1.5 TELESCOPE ALIGNMENT WITH STARSHADE

- This mode is invoked during the Exoplanet phase.
- The telescope is using the alignment system to detect the location of the Starshade and give it instructions of how to move to get into the box. This is the fine alignment step of the alignment procedure.

4.1.6 TELESCOPE SCIENCE OPS WITH STARSHADE

- This mode is invoked during the Exoplanet Science Ops phase.
- The telescope is observing, using the alignment system to detect the location of the Starshade, and instructing the Starshade when to fire thrusters to maintain alignment.

4.1.7 TELESCOPE THRUSTER FIRING

- This mode is uses the RCS thrusters to perform delta-v burns.
- During the DC&TC phase, this mode will be used for trajectory correction and other maneuvers (TBR).
- During the Calibration and Commissioning phase and the Science Operations phase, this mode can be used for orbit maintenance DeltaVs and momentum unloading.
- ACS sensors and actuators include IRU and RCS (TBD).

4.1.8 TELESCOPE SAFE HOLD

- This mode is used for nominal and/or contingency operations. There are several levels of safe hold; the level selected will depend on the cause of safe hold entry and the status of the spacecraft subsystems
- Safe mode is invoked after certain faults that prevent continuing with planned observations. This is a wheel based mode.
- Safe hold mode can also be used during nominal operations for deployment, other maneuvers (TBR), and standing by during the D&TC, CCC, and Science Operations phases.
- Safe Hold mode protects against failures jeopardizing the Telescope safety (reqt for sun to never go down the barrel of telescope).
- Some safe hold levels switches to the redundant Single Board Computer (SBC).

Safe Hold Mode is a Sun Pointing Mode for the solar arrays, but the Telescope enters this mode in response to certain fault triggers. Redundant components can be used when entering Safe Hold Mode.

Following a switch to the redundant Spacecraft processor, the Spacecraft allows for retention of data of the swapped-from processor for later access by the Ground for use in anomaly resolution. In addition, the swapped-to processor will have current information available to determine Telescope configuration post swap. Spacecraft fault management will ensure that sun constraints are not violated.

4.1.9 TELESCOPE SURVIVAL

- The survival mode protects against major faults using an independent processor.
- Survival mode is invoked after certain faults that prevent continuing with planned observations. These faults are more severe than the ones invoked for Safe Hold mode.
- The ACS is in sun point mode.
- Telescope control switches to the Input/Output Module (IOM).
- C&DH and ACS hardware redundant sides are already switched by the safe hold mode (TBD).

Survival Mode is similar to Safe Hold mode with additional load shedding to ensure minimum power draw. Components not needed to ensure health and safety of the Telescope will be turned off. Attitude control and communication links to the Ground will be maintained in this mode.

This mode is entered by reset or power cycle of the Spacecraft Central Telemetry Processor (TBD). For this reason, Survival Mode determines Telescope configuration based on information stored in non-volatile memory. The Ground updates the electrically erasable programmable read-only memory (EEPROM) parameters as necessary to ensure Survival Mode entry in the appropriate configuration. Survival temperatures are maintained and sun constraints met.

4.2 SCIENCE TELESCOPE MODES MAPPED TO MISSION PHASES

	MISSION PHASES	Pre-Launch	Launch	D&TC	CCC	Science Operations 1 -- General Astrophysics	Science Operations 2 -- Exoplanets
TELESCOPE MODES	Launch	X	X				
	Wheel Attitude Maneuver			X	X	X	X
	Acquisition Without Starshade				X	X	
	Telescope Science Ops Without Starshade					X	
	Alignment With Starshade						X
	Telescope Science Ops With Starshade						X
	Thruster Firing			X	X	X	X
	Safe-Hold			X	X	X	X
	Survival			X	X	X	X

Table 4.2.1: Science Telescope Spacecraft Modes Mapped to Mission Phases

4.3 STARSHADE MODES

The Starshade Spacecraft modes (Normal and Contingency) are defined as the following:

- Starshade Launch
- Starshade Wheel Attitude Maneuver
- Starshade EP Thruster firing
- Starshade RCS Thruster firing
- Starshade Normal Pointing
- Starshade Safe Hold
- Starshade Survival

4.3.1 STARSHADE LAUNCH

- The attitude control subsystem is in standby mode.
- Coarse sun sensors, fine sun sensors and inertial reference unit (IRU) are enabled.
- Sensor data is processed but actuator commands are not allowed.

4.3.2 STARSHADE WHEEL ATTITUDE MANEUVER

- Attitude Maneuver mode is used to slew the Starshade to a new attitude.
- Sensors and actuators include IRU, RWA, and HGA Drive.

4.3.3 STARSHADE EP THRUSTER FIRING

- This mode is performed using the EP subsystem.
- EP thruster firing is used while doing Coarse Alignment in the Science phase. It might also be used to perform Delta-V burns during the D&TC Phase (TBR).

4.3.4 STARSHADE RCS THRUSTER FIRING

- This mode is performed using the RCS subsystem.
- RCS thruster firing is used while doing Medium and Fine Alignment in the Science phase. It is also be used to perform Delta-V burns during the D&TC Phase and for momentum offloading in any phase.

4.3.5 STARSHADE NORMAL POINTING

- Normal Pointing mode can be used during nominal operations for deployment, other maneuvers (TBR), and standing by during the D&TC, CCC, and Science Operations phases.
- This mode can use the Astrometric Sensor on the Starshade to determine the alignment of the Starshade to the Telescope during the General Astrophysics part of the Science Phase (TBD) or for taking ancillary science data during any phase.

4.3.6 STARSHADE SAFE HOLD

- Safe mode is invoked after certain faults that prevent continuing with planned observations. This is a wheel based mode.
- Starshade control continues under spacecraft Single Board Computer (SBC) primary side and C&DH and ACS primary string equipment.

- The ACS mode used for the Starshade safe mode is the sun point mode which ensures a sun safe attitude.
- ACS sensors and actuators include coarse and fine sun sensors, IRU, and RCS.

4.3.7 STARSHADE SURVIVAL

- The survival mode protects against major faults using an independent processor.
- The ACS is in sun point mode.
- Telescope control switches to the Input/Output Module (IOM).
- C&DH and ACS hardware redundant sides are already switched by the safe mode.

4.4 STARSHADE SPACECRAFT MODES MAPPED TO MISSION PHASES

	MISSION PHASES	Pre-Launch	Launch	D&TC	CCC	Science Operations 1 -- General Astrophysics	Science Operations 2 -- Exoplanets
STARSHADE MODES	Launch	X	X				
	Wheel Attitude Maneuver			X	X	X	X
	EP Thruster firing			X	X	X	
	RCS Thruster firing			X	X	X	X
	Normal Pointing			X	X	X	X
	Safe-Hold			X	X	X	X
	Survival			X	X	X	X

Table 4.4.2: Starshade Spacecraft Modes Mapped to Mission Phases

4.5 SPACECRAFT ATTITUDE CONTROL SUBSYSTEM COMPONENTS AND SPACECRAFT MODES

4.5.1 SCIENCE TELESCOPE SPACECRAFT (TBR)

Telescope Mode	Star Tracker	Gyro	CSS	FGS	Wheels	Thrusters
Launch						
Wheel Attitude	X	X			X	
Acquisition	X	X			X	
Alignment	X	X		X	X	
Ops without SS	X	X		X	X	
Thruster	X	X				X
Safe hold		X	X		X	X
Survival		X	X		X	X

Table 4.5.1: Science Telescope Spacecraft Modes and ACS Components

4.5.2 STARSHADE SPACECRAFT

Starshade Mode	Star Tracker	Gyro	CSS	FGS	Wheels	Thrusters
Launch						
Wheel Attitude	X	X			X	
EP Thruster	X	X			X	EP
RCS Thruster	X	X			X	RCS
Normal Pointing	X	X		X	X	
Safe hold		X	X		X	RCS
Survival		X	X		X	RCS

Table 4.5.2: Starshade Spacecraft ACS Operating Modes

5.0 OPERATIONAL SCENARIOS

#	Title	Description
OS1	Prelaunch & Launch Operations	This systems scenario provides a description of the major events of the prelaunch phase that begins with the Terminal countdown and ends with EELV launch. The NWO S/C is encapsulated in the EELV on the KSC pad. This scenario provides a description of the major events of the EELV launch phase with the NWO as the Payload. The S/C team at KSC hands over the S/C responsibility to the MCC at the EELV 'Tower Clear' as announced by the Launch Director. The launch phase is tracked. The EELV controls the NWO attitude until S/C separation. This scenario ends at spacecraft separation from the EELV. This scenario has not yet been developed.
OS2	Deployment, Checkout, and Trajectory Correction Scenario	This systems scenario provides a description of the major events of Deployment, Checkout, and Trajectory Correction phase. This scenario begins at the end of the previous scenario (OS1) following spacecraft separation from the launch vehicle. This scenario covers the spacecraft deployment activities and several of the midcourse correction burns needed to reach L2 safely. See separate file for this scenario: NWO OS2_DCTC Scenario_2-10-09_teamprop.doc
OS3	Exoplanet Observation Commissioning	This scenario occurs once the Starshade arrives in the vicinity of the telescope at L2. We begin checkout, calibration, and commissioning of the alignment and control required for exoplanet observations. Commissioning (completed 6 months (TBD) after launch) includes telescope, Starshade, and spacecraft, and mission-level operations. This phase ends with Telescope and Starshade commissioning certifications (declared fit for normal exoplanet operations). This scenario has not yet been developed.

OS4	Science Operations	This scenario begins at the end of the previous scenario (OS3). This scenario covers the Exoplanet and General Astrophysics science operations. Science Operations are also known as Normal or nominal operations. Science operations occur when NWO is performing its primary mission. This scenario can begin once Commissioning is complete and is the phase in which nominal science operations and supporting activities occur. Nominally, the Spacecraft executes the on-board observation plan and periodic Ground Segment contacts take place to upload the observation plan, determine the Spacecraft orbit, and download science and engineering data. This phase lasts at least 5 years (TBR) with a 10 year goal.
		▪ Science Ops 1: General Astrophysics:
		    ▪ Telescope and Starshade not communicating
		▪ Science Ops 2: Exoplanet:
		    ▪ Telescope and Starshade communicating
		See separate file for this scenario: OS4_Science Ops

		scenario_NorthropGrumman_2-10-09_NWOteamprop.doc