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Design Requirements for the SNAP Telescope Structures

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Abstract

This document summarizes thermal, mechanical, stability, and other requirements and assumptions used by HYTEC in designing structural subsystems and components for the SNAP telescope. This is a working document; it is intended to be continuously updated and refined to reflect our best estimate of the baseline configuration and design requirements, and document the assumptions made in initial design studies. It should eventually evolve into a requirement document per se.

- High priority TBD items: red, double underline
- Lower priority TBD items: blue, single underline

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SNAP

Revision Log

Rev.	Date	Author(s)	Summary of Revisions/Comments
-	06/05/00	E. Ponslet	Initial draft release, lots of TBD.
A	06/20/00	E. Ponslet	updates and changes throughout based on 06/08/2000 LBNL/HYTEC telecon.
B	12/12/00	E. Ponslet	2: subsystem denomination, coordinate system 5.4.1: reaction wheel info added, and other minor changes 6.4.1: minor changes 7.1: major changes to mass allocations and dimensions 7.5.3: rewritten, new requirements 7.9: section removed 8: new reference documents and updated ones

Table of Contents

1. Definitions

- SNAP: Supernovae Acceleration Probe.
- CTE: Coefficient of Thermal Expansion.
- TML: Total Mass Loss[1].
- CVCM: Collectible Volatile Condensable Material[1].
- GEVS: General Environmental Verification Specification, see reference [4].
- DOF: Degree of Freedom.

2. The SNAP Telescope and Local Coordinate System

The baseline concept for SNAP uses a 3-mirror anastigmatic telescope. Our baseline structural concept is shown in Figure 1, where subsystem designations are also identified. Note that other arrangements are also being considered.

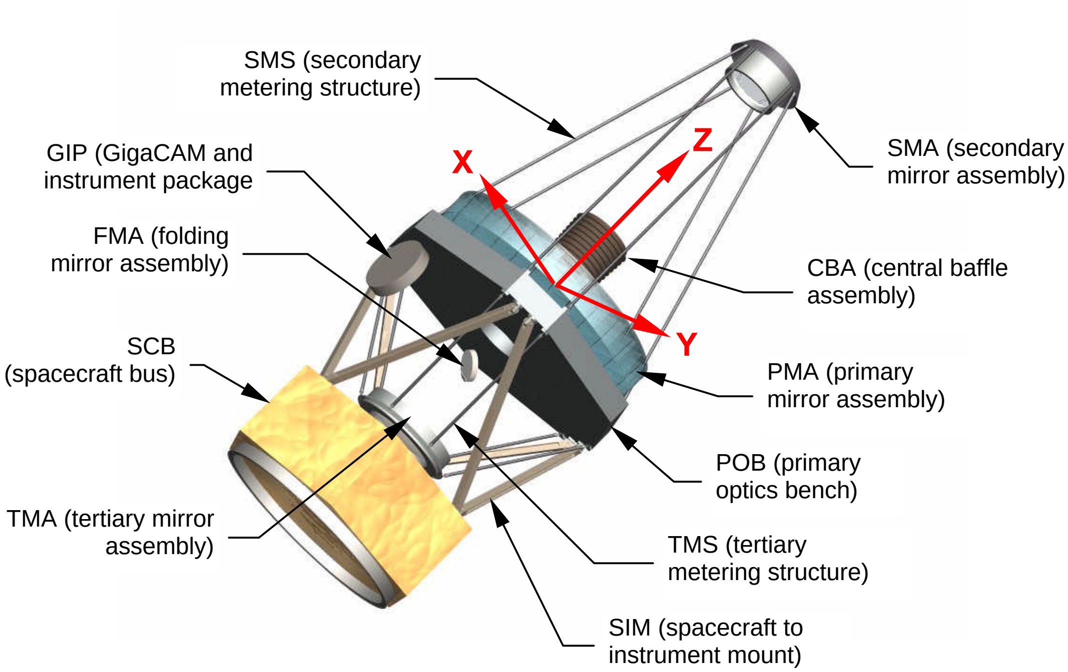

Figure 1: Conceptual rendering of the SNAP telescope; some key telescope components and the local axis system are identified.

Some key components of the telescope are:

- A primary optics bench (POB), attached to the spacecraft bus with a kinematic (or near-kinematic) interface structure (SIM). All other components of the instrument are supported by this primary optics bench.

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[1] as measured per ASTM E595-90.

- A large primary mirror assembly (PMA) with its mounts, supported directly on the primary optics bench.
- A secondary mirror assembly (SMA: mirror, backing structure, baffle, and actuators), supported off the primary optics bench by the secondary metering structure (SMS).
- A tertiary mirror assembly (TMA: mirror, backing structure, baffle, and actuators), supported off the primary optics bench by the tertiary metering structure (TMS).
- A flat folding mirror assembly (FMA: mirror, backing structure, and actuators) supported off the primary optics bench by the folding mirror support (FMS)
- A central baffle assembly (CBA) mounted on the primary optics bench and protrutding through the primary mirror center hole towards the secondary mirror
- A detector array assembly (GIP: GigaCAM and other focal plane detectors) at the focal plane.
- A large cylindrical baffle around the primary mirror (PBA: primary baffle assembly not shown), likely attached directly to the primary optics bench.
- A large cylindrical shield around the entire instrument (PSH) which also serves as the support structure for solar arrays, likely attached directly to tha spacecraft bus.

For the purpose of instrument design, we define a unique instrument-fixed reference frame. The Cartesian frame is shown in Figure 1 and is defined as follows:

- The origin of the coordinate system is at the center of the primary mirror surface.
- The Z-axis lies along the line of sight of the telescope, pointing in the direction of observation (i.e. from the primary to the secondary mirror).
- The X-axis is normal to and points toward the detector array/focal plane and the cold side of the spacecraft.
- The Y-axis completes the right-hand system.

3. Launch Vehicle

A Delta IV Medium launch vehicle (4 meter payload fairing) is the current baseline for the SNAP mission[1]. Mechanical loading conditions and other mechanical design requirements for Delta IV payloads are defined in the *Delta IV Payload Planners Guide*[2].

4. Orbit Conditions and Mission Parameters

At this stage, a lunar assist high earth orbit is assumed. As stated in the SNAP proposal, that orbit has a number of advantages related to the thermo-mechanical design of the telescope structure:

- Earth albedo and thermal radiation are low.
- The time between eclipses is long (14 day orbit).
- The orbit is entirely outside the radiation belts.

Other orbital parameters TBD.

4.1 Mission Timeframe and Duration

SNAP is expected to be a 5 year mission, with a launch in 2008 .

4.2 Earth Albedo

As far as thermal input into structural elements of the telescope, the effect of the earth albedo will at first be assumed negligible compared to direct solar input.

4.3 Solar Radiation

For the time being, a standard solar constant of 1358 W/m^2 will be assumed.

4.4 Micro-Meteorite

TBD - not an issue at this stage; will need size/mass/velocity/rates

4.5 Charged Particle Radiation

TBD - minor issue at this stage; will need mission duration and fluxes / total doses

A total dose of 20 kRad over the life of the mission will be used for initial design studies.

5. Mechanical Environment

5.1 Assembly, Handling, Transportation

The entire assembly of the telescope is assumed to be performed at atmospheric pressure (100 kPa) under gravity (9.81 m/s^2). It is assumed that the instrument will only be supported by its "kinematic" attachment points on the primary mirror optical bench. It is also assumed that gravity loads can occur in any direction relative to the instrument.

The mechanical environment during assembly, handling, and transport is otherwise assumed milder than the other conditions (testing, launch, and orbit) listed in this section (i.e. lower static, vibration, acoustic, and shock loads). Note that this statement implicitly places constraints on handling practices, shipping containers, etc.

5.2 Environmental Verification Testing

Prototype, protoflight, and acceptance tests and levels will be defined following the guidelines of the GEVS[4], combined with the *Delta IV Payload Planners Guide*[2]. Figure 2 lists test levels as recommended in the GEVS.

Test	Prototype (Qual.)	Protoflight (Qual.)	Acceptance
Structural Loads[1] Test Level Analysis (show positive margins for all ultimate failure modes)	1.25 x Limit Load 1.4 x Limit Load	1.25 x Limit Load 1.4 x Limit Load	1.0x Limit Load 1.4 x Limit Load
Acoustics Level[2] Duration	Limit Level + 3dB 2 minutes	Limit Level + 3dB 1 minute	Limit Level 1 minute
Random Vibration Level[2] Duration	Limit Level + 3dB 2 minutes/axis	Limit Level + 3dB 1 minute/axis	Limit Level 1 minute/axis
Sine Vibration[3] Level Sweep Rate	1.25 x Limit Level 2 oct/min	1.25 x Limit Level 4 oct/min	Limit Level 4 oct/min
Acceleration (Centrifuge) Level Duration	1.25 x Limit Level 1 minute	1.25 x Limit Level 30 seconds	Limit Level 30 seconds
Mechanical Shock Actual Device Simulated	2 actuations 1.4 x Limit Level 2 x Each Axis	2 actuations 1.4 x Limit Level 1 x Each Axis	1 actuations Limit Level 1 x Each Axis
Thermal-Vacuum	Max./min. predict. ± 10°C	Max./min. predict. ± 10°C	Max./min. predict.
Thermal Cycling[4]	Max./min. predict. ± 15°C	Max./min. predict. ± 15°C	Max./min. predict. ± 5°C
EMC & Magnetics	As Specified for Mission	Same	Same

1 - If qualified by analysis only, positive margins must be shown for load factors of 2.0 on yield and 2.6 on ultimate. Composite materials cannot be qualified by analysis alone.

Note: Test and Analysis levels for beryllium structure are 1.4 x Limit Level for both qualification and acceptance testing, and 1.6 x Limit Level for analysis on ultimate. Also composite structure, including metal matrix, requires acceptance testing to 1.25 x Limit Level.

2 - As a minimum, the test level shall be equal to or greater than the workmanship level.

3 - The sweep direction should be evaluated and chosen to minimize the risk of damage to the hardware. If a sine sweep is used to satisfy the loads or other requirements, rather than to simulate an oscillatory mission environment, a faster sweep rate may be considered, e.g., 6-8 oct/min to reduce the potential for over stress.

4 - It is recommended that the number of thermal cycles be increased by 50% for thermal cycle (ambient pressure) testing.

Figure 2: test levels as specified in NASA GEVS (reproduced from [4]).

Note 2 in Figure 2 points to a minimum requirement for workmanship random vibration tests on space hardware , even in the absence of known random vibration levels for the specific launch vehicle (see section 5.3.2.1). That minimum test requirement is detailed in Figure 3.

Frequency (Hz)	ASD Level (G^2/Hz)
20	0.01
20-80	+3 dB/oct
80-500	0.04
500-2000	-3 dB/oct
2000	0.01
Overall	6.8 G_{rms}

The plateau acceleration spectral density level (ASD) may be reduced for components weighing between 45.4 and 182 kg, or 100 and 400 pounds according to the component weight (W) up to a maximum of 6 dB as follows:

		Weight in kg	Weight in lb
dB reduction	=	10 log(W/45.4)	10 log(W/100)
$ASD_{(plateau)}$ level	=	0.04•(45.4/W)	0.04•(100/W)

The sloped portions of the spectrum shall be maintained at plus and minus 3 dB/oct. Therefore, the lower and upper break points, or frequencies at the ends of the plateau become:

F_L = 80 (45.4/W) [kg] F_L = frequency break point low end of plateau
= 80 (100/W) [lb]

F_H = 500 (W/45.4) [kg] F_H = frequency break point high end of plateau
= 500 (W/100) [lb]

The test spectrum shall not go below 0.01 G^2/Hz. For components whose weight is greater than 182-kg or 400 pounds, the workmanship test spectrum is 0.01 G^2/Hz from 20 to 2000 Hz with an overall level of 4.4 G_{rms}.

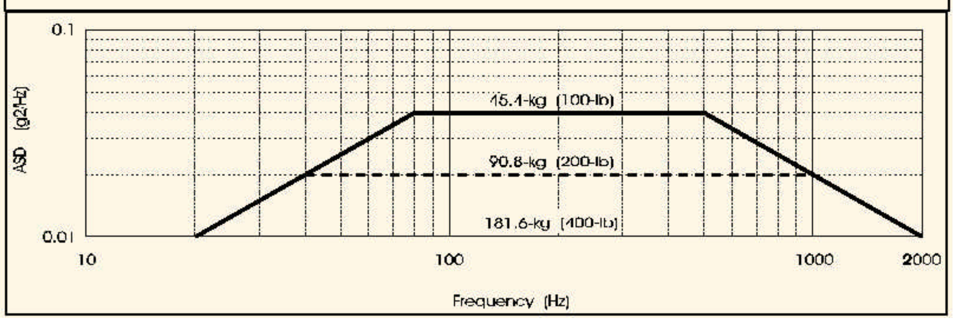

Figure 3: minimum random vibration workmanship test requirement from NASA GEVS[4].

5.3 Launch

5.3.1 Pseudo-Static Loads

For preliminary design of an entire payload or large subsystems, static acceleration and low frequency transient launch loads are typically reduced to pseudo static loads. This approximation is valid as long as dynamic coupling between the payload and the launch vehicle is kept low by requiring minimum payload natural frequencies as stated in Section 7.3.

The design limit pseudo-static load factors for the spacecraft / instrument assembly are defined in the *Delta IV Payload Planners Guide*[2] and reproduced in Table 1.

load case	axial (g)	transverse (g)
1	+6.5[a]	±0.5
2	+2.4[a]	±2.0
3	–0.2[a]	±2.0

[a] positive axial load factors produce compression of the payload.

Table 1: design limit load factors for Delta IV medium; for each load case, axial and transverse accelerations apply simultaneously.

5.3.2 Dynamic Loads

5.3.2.1 Random Vibrations

As noted in the *Delta IV Payload Planners Guide*[2], no significant level of random vibration is transmitted to the payload during a Delta IV launch. Direct random vibration input from the separation ring is therefore ignored.

Note however that random vibration excitation of the payload will still occur during launch but is dominated by acoustic inputs as defined in Section 5.3.3.

In addition, note that the *GEVS*[4] imposes a minimum requirement on workmanship testing of flight equipment that involves a broad spectrum random vibration test (see Section 5.2).

5.3.2.2 Sine Vibrations

Sine-like vibrations at low frequencies occur during launch and may excite more flexible subsystems and appendages of the payload. Maximum expected levels are defined in the *Delta IV Payload Planners Guide*[2] and reproduced in Table 2.

Axis	Frequency (Hz)	Max. flight level
Thrust	5 to 6.2 6.2 to 100	1.27 cm P-P 1.0g 0-P
Lateral	5 to 100	0.7g 0-P

Table 2: Sinusoidal vibration flight levels for Delta IV medium.

5.3.3 Acoustic Loads

Acoustic loading of the payload occurs during launch. Maximum expected sound pressure levels are defined in the *Delta IV Payload Planners Guide*[2] and reproduced in Figure 4. Acoustic inputs are especially important for components of the payload with large exposed areas.

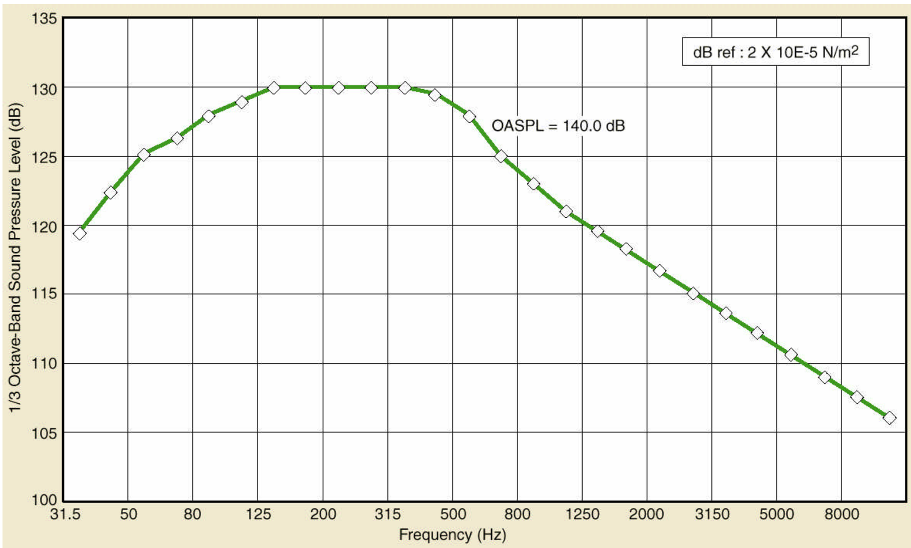

Figure 4: Third-octave sound pressure spectrum inside Delta IV medium 4m fairing during launch.

5.3.4 Pyroshock Loads

Pyroshock loads imparted on the payload by the separation from the launch vehicle are defined in the Payload Planners Guide[2]. Pyroshock loads are unliquely to be a factor in the design of the large metering structures. Shock loads will therefore be ignored in initial studies.

5.3.5 Aerostatic Air Pressure

The air pressure history inside the payload fairing during a Delta IV launch is given in Figure 5.

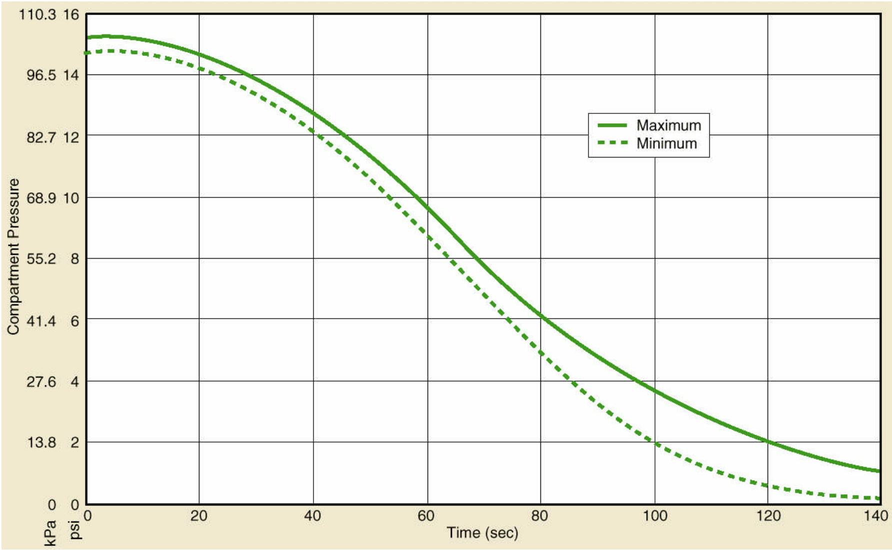

Figure 5: air pressure history inside Delta IV Medium 4 meter payload fairing during launch.

5.4 Orbit

In orbit, it is assumed that there are no static, pseudo-static, or shock loads on the spacecraft/instrument. All known sources of mechanical loads/vibrations in orbit are listed below.

5.4.1 On Board Vibration Sources

5.4.1.1 Reaction Wheels

The baseline spacecraft will be equipped with four reaction wheel assemblies (RWA-15 with microbalance, from L3-communications) mounted on the spacecraft bus in a square pyramid arangement.

Vibration input from RWA imbalance will be estimated based on the specifications shown inTable 3[6].

Feature	Value	Comments
Angular Momentum	+/- 20 Nms	
Speed Range	+/- 2200 RPM	also equal to 36.7 Hz
Reaction Torque	0.75 Nm	
Mass of rotor	5.7 kg	
Total mass	14.9 kg	
Static Imbalance	3.6×10^{-6} kg.m @ BOL	about twice as much at EOL
Dynamic Imbalance	0.92×10^{-6} kg.m^2 @ BOL	about twice as much at EOL

Table 3: Key mechanical specifications of RWA-15 micro-balanced reaction wheel assemblies from L3-Communications[6].

5.4.1.2 Mirror Actuators

Mirrors actuation will likely be used only for periodic realignment of the optics, with the telescope off-line. Any vibrations caused by these motions are expected to damp out before telescope operation is resumed.

5.4.1.3 Other

The only other identified sources of on board dynamic loads are the filter wheels and shutter. TBD: not an essential issue at this stage; input will eventually need to be characterized as force VS time / energy spectrum.

6. Hygro-Thermal Environment

6.1 Assembly, Handling, Transportation

The entire assembly of the telescope is assumed to be performed at room temperature (21ºC), in clean rooms with a maximum of 50% RH.

The thermal environment during assembly, handling, and transport is otherwise assumed milder than the other conditions (testing, launch, and orbit) listed in this section (i.e. lower maximum temperature, higher minimum temperature, lower heat flows in and out of the instrument, and lower static, vibration, acoustic, and shock loads). Note that this statement implicitly places constraints on handling practices, shipping containers, etc.

6.2 Environmental Verification Testing

Prototype, protoflight, and acceptance tests and levels will be defined following the guidelines of the GEVS[4], combined with the launch vehicle payload design manual[2]. Figure 2 lists test levels as recommended in the GEVS.

6.3 Launch and Launch Preparation

The thermal environment before and during launch is dictated by conditions inside the MST and payload fairing. Temperature and humidity limits during those phases are specified in the Payload Planners Guide[2].

Although the payload agency has some freedom to impose stricter requirements, the default temperature and humidity limits are:

- Temperature: 10 to 29.4ºC ± 2.8ºC
- Relative humidity: 20 to 55%

During launch, the temperature of the payload may increase somewhat due to exposure to the rising temperature of the inside surfaces of the fairing. In many cases this condition is not a driving design case. We will initially assume that this is not a driving case; that assumption should be tested by comparing temperature extremes for other conditions (survival for example) to the fairing temperatures shown in the Figure.

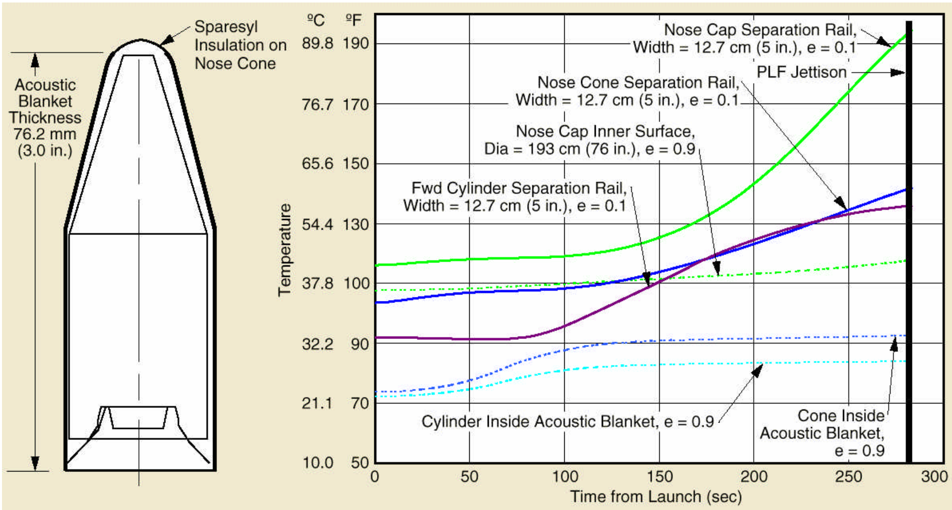

Figure 6: inside surface temperature of Delta IV medium 4-m payload fairing during launch.

6.4 Orbit

6.4.1 Baseline Thermal Design Philosophy

In orbit, the line of sight of the SNAP telescope (Z direction, see Figure 1) will always be pointed away from the sun to explore deep space. The same side of the spacecraft (-X side, see Figure 1) will always be pointed toward the sun (this always keeps the pixel detector radiators on the cold, +X side). There may be a moving cover to optically close the main aperture on demand for protection from contamination before and during launch and possibly for added safety against accidental sun-pointed attitudes.

In operation, it is envisioned that the primary optics bench, primary mirror, and optics components mounted behind it will operate around 250ºK (-23ºC). The pixel detector will be maintained at about 150ºK (-123ºC). It will be thermally isolated from the rest of the instrument and use of a dedicated radiator for temperature control. Without heaters, the secondary mirror assembly and its metering truss will tend to operate at very low temperatures (could approach 4ºK) since they are shielded for solar radiation and directly exposed to deep space. Because of the steady attitude of the spacecraft relative to the sun and the high orbit, large *transients* in the temperature of the secondary mirror structures are not expected. Material requirements may impose the use of heaters/controllers to maintain the temperatures of those elements at a stable and more reasonable value (TBD).

Because the spacecraft is continuously exposed to the sun on one side (directly or indirectly depending on whether a separate sun shield is used), a transverse thermal gradient will likely develop in that structure. This is not a problem in itself as long as all metering structures are mechanically independent of the baffle structure. However, radiative coupling with the secondary metering truss may induce a transverse thermal gradient in that structure, and potentially lead to significant β and Y movements of the secondary mirror. High thermal conductivity materials may be used to help reduce such gradients. Heat pipes, however are not acceptable because of dynamic and inertial disturbances induced by the fluid flow.

Conductive coupling of the secondary metering structure with the primary optical bench may also induce a longitudinal thermal gradient in the secondary metering structure.

6.4.2 Temperature Extremes in Survival Mode

Without the use of survival heaters, the lowest temperatures reached during a full eclipse portion of the orbit would be extremely low, particularly in those structures directly exposed to deep space (such as the main baffle and the secondary mirror assembly and its metering structure). Because of this, it is likely that survival heaters will be used. Design requirements for those heaters will in part derive from minimum survivable temperatures for the various structures.

TBD - what would be a reasonable MAXIMUM temperature? A typical value of +50ºC may be a good starting point. Also see remark in Section 6.4.1.

6.4.3 Nominal Temperature Distribution and Fluctuations in Normal Operation

Steering mirror(s) will provide occasional correction capability for linear and angular dimensional changes. However, short term temperature fluctuations may produce instabilities that cannot easily be corrected for. To limit these instabilities, very low CTE materials will be used throughout the instrument structures. With the extremely tight stability requirements for this telescope, it is likely that a viable design will require a combination of measures to minimize temperature induced instabilities: ultra-low CTE materials, controlled heaters, etc.

TBD: To evaluate the design, a nominal (in operation) temperature distribution and a perturbation will eventually need to be defined so that short term instabilities can be evaluated. In the meantime, we will assume that very low effective CTE (say -0.1 ppm/ºK < CTE < 0.1 ppm/ºK) is a requirement for all critical metering structures. This would insure that thermally driven instabilities in the secondary metering structure for example are less than about 0.1µm/ºK.

7. Design Requirements

7.1 Assumptions on Overall Dimensions and Mass Properties

The assumed optical configuration and mass properties[7] for the SNAP telescope are summarized in Figure 7 and Table 4. These numbers are used as assumptions in initial design of supporting structures.

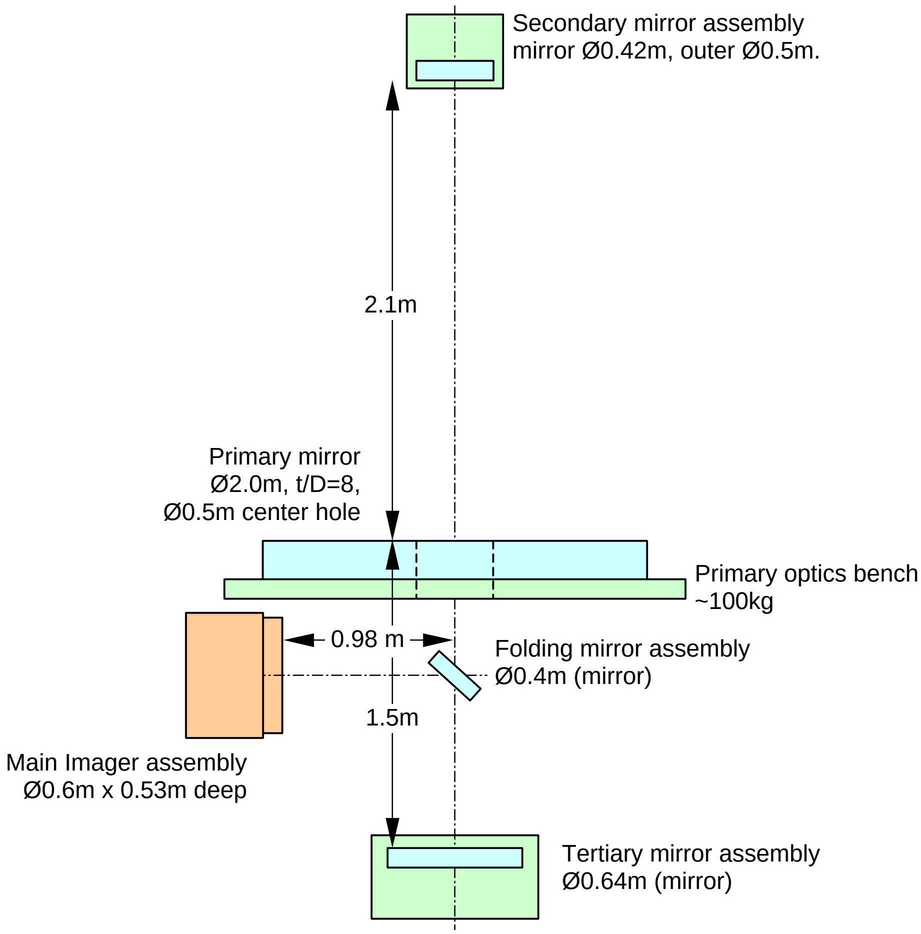

Figure 7: Key geometric and mass parameters of SNAP for use in conceptual design of telescope structures.

	Component / Subsystem	Mass (kg)	approx CM location (m)			Notes
			X	Y	Z	
POB	primary optics bench	150	0	0	-0.4	composite egg-crate platform
PBA	primary baffle (around primary mirror, abover and below POB)	150	0+	0	2	attached to outer edge of optics bench.
PSH	thermal shield for primary baffle	150	0+	0	2	around primary baffle, attached to spacecraft bus (may not be separate from primary baffle).
PMA	primary mirror assembly (including mounts)	350	0	0	-0.1	
SMA	secondary mirror assembly (mirror, backing structure, baffles, actuators,…)	22	0	0	2.25	
SMS	secondary metering structure	10	0	0	1.05	composite truss
TMA	tertiary mirror assembly (mirror, backing structure structure, actuators,…)	40	0	0	-1.7	
TMS	tertiary metering structure	10	0	0	-1.2	composite truss
CBA	central baffle assembly	5	0	0	0.35	aluminum shell
FMA	folding mirror assembly (folding and pickup mirrors, backing structure, actuators,…)	4	0	0	-0.9	
FMS	folding mirror support structure	1	0	0	-0.9	composite spider
	Focal plane instrument package (FIDO)	150	1.3	0	-0.9	GigaCAm and other focal plane instruments, packaged (assuming off-detector electronics is on bus)
	filter wheels/shutter	85	0.4	0	-1.3	filter wheel and shutter assumed single package
	other instruments on POB	30	0	0	-0.5	Star trackers, gyroscopes, etc… assumed uniformly distributed
	TOTAL mass of instrumentation mounted to "back" side of optics bench	265				
	spacecraft-instrument kinematic interface	40	0	0	-1.2	Aluminum truss
SCB	spacecraft	400 / 500	0	0	-2.1	mass range=dry / wet
	off-detector instrument electronics	120	0	0	-2	mounted on spacecraft bus
	TOTAL mass of spacecraft bus	520 / 620				mass range=dry / wet
	TOTAL	1717 / 1817				mass range=dry / wet

Table 4: Assumed/estimated masses and locations of telescope components.

7.2 Mass Budget Limits and Center of Mass Requirements

Assuming a Delta IV launch vehicle, the upper limit on the spacecraft mass is much larger than the currently anticipated mass. For this reason, the structural design will initially be treated as mass-unlimited.

7.3 Stiffness

As specified in the Delta IV payload manual[2], fixed boundary (at the separation plane) fundamental frequencies of the entire spacecraft and instrument assembly must be greater than 27 Hz in the launch direction and 10 Hz in the transverse directions. In addition, all secondary structures of the payload must have natural frequencies greater than 35 Hz.

Natural frequencies of structural elements and the entire spacecraft assembly may have to be kept safely away from any dominant frequency(ies) of excitation from the reaction wheels.

7.4 Damping

Because all structures will be designed for high natural frequencies, the time required to damp out responses to transients should be relatively short. It is not anticipated that special damping treatments will be necessary or even practical.

7.5 Dimensional Stability

Because SNAP is a high-resolution telescope, its geometric and dimensional stability are critical to performance. Temperature variations in orbit and temperature difference between initial alignment and on-orbit conditions will tend to disturb alignment of optical components through thermal expansion. At least three distinct approaches can be used (alone or in combinations) to minimize these effects:

- Minimize on-orbit temperature variations and ground-space temperature differences with heaters, blankets, coatings, and active thermal control.
- Provide means of actively controlling the geometry and/or pointing of the telescope in orbit through mirror positioning, reshaping actuators, or spacecraft attitude control.
- Design the telescope structures to minimize temperature-induced deformations through the use of near-zero CTE materials.

The choice of a particular strategy obviously affects the stability requirements on the structures. It is likely that SNAP will require a combination of all 3 approaches. Whatever strategy is used, some limits on dimensional changes in the support structure will have to be imposed. Those limits are defined below in 6 degrees of freedom in terms of the positional stability of:

- The primary mirror support bench relative to the spacecraft.
- The secondary, tertiary, and folding mirror backing structures relative to the primary mirror support bench.
- The imaging plane support structure relative to the primary mirror support bench.

Note that the numbers listed below pertain to the structures supporting the mirror/actuator assemblies and not the mirror surfaces themselves. In addition, instabilities due to dimensional changes in the interface elements between the supporting structures and mirrors, or in the mirrors themselves, are not included in these numbers (since they are not at this time included in the design problem).

Note: if active mirror control and/or attitude control is used, the stability requirements will likely become a function of frequency (i.e. requirements may be looser in the bandwidth of the controller). Also, because of integration times, the effect of static and transient instabilities may be different, leading to separate requirements for different frequency ranges (?).

7.5.1 Effective Coefficient of Thermal Expansion

As stated earlier, with the extreme structural stability requirements of this mission, ultr-low CTE materials will be required throughout the telescope structures. An initial goal of -0.1ppm/ºK < CTE < 0.1ppm/ºK for the effective CTE of metering structures will be used as a guideline for initial studies.

7.5.2 Loss of Alignment due to Gravity Sag, Launch, and Earth-Orbit Temperature Differences

Because mirror steering actuators will be used trhoughout the optical path, realignment/refocusing will be possible in orbit and the telescope will not rely on pre-launch precision alignment. The magnitude of the Earth-to-Orbit losses of alignment will be one of the contributors to define the required range of the steering actuators.

7.5.3 Jitter in Normal Operation

The bandwith for the spacecraft attitude control system is expected to be 0 to 5 Hz. Motions of telescope components at frequencies lower than that can be - at least partially - compensated for by the ACS. On the other hand, motions occuring with frequencies greater than 5 Hz cannot be compenstaed for and call for much tighter stability requirements. In view of this, separate requirements are listed below for those two frequency range.

7.5.3.1 Allowable motions at frequencies lower than 5 Hz

relative alignment of	Maximum Peak-Peak Deviation					
	X (µm)	Y (µm)	Z (µm)	α (µradian)	β (µradian)	γ (µradian)
primary to ACS instruments	TBD	TBD	TBD	TBD	TBD	TBD
secondary to primary	5.2	5.2	TBD	8.4	8.4	TBD
tertiary to primary	TBD	TBD	TBD	TBD	TBD	TBD
folding to primary	TBD	TBD	TBD	TBD	TBD	TBD
imaging to primary	TBD	TBD	TBD	TBD	TBD	TBD

Table 5: Stability requirements for motions occuring at frequencies lower than 5 Hz.

7.5.3.2 Allowable motions at frequencies greater than 5 Hz

relative alignment of	Maximum Peak-Peak Deviation					
	X (µm)	Y (µm)	Z (µm)	α (µradian)	β (µradian)	γ (µradian)
primary to ACS instruments	TBD	TBD	TBD	TBD	TBD	TBD
secondary to primary	0.5	0.5	1.2	0.4	0.4	TBD
tertiary to primary	1.2	1.2	19	0.7	0.7	TBD
folding to primary	TBD	TBD	TBD	TBD	TBD	TBD
imaging to primary	TBD	TBD	TBD	TBD	TBD	TBD

Table 6: Stability requirements for motions occuring at frequencies greater than 5 Hz.

7.6 Optical Issues

7.6.1 Mirror Obscuration by Support Structures

There are two issues related to the obscuration of the optical path by the secondary metering structure (the other mirror support structures potentially lie entirely outside the optical path):

- the percentage of the cross sectional area of light collection blocked by those structures, reulting in a loss of light; A design goal of 5% obscuration will be used.
- the angular layout of support members and the resulting diffraction pattern. Examples of diffraction patterns due to various support configurations are shown in Figure 8. A smaller number of diffraction spikes is preferable, making 0/90/180/270º layouts optimal.

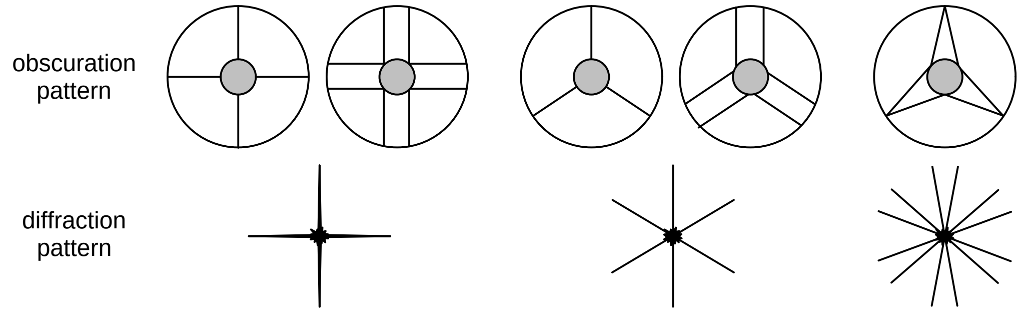

Figure 8: angular arrangement of secondary mirror support members and its effect on diffraction pattern.

In addition, the obscuration pattern should not change through the entire field of view of the instrument, or +/- 0.7º from axial; this applies for example to support layouts where secondary memebrs may "hide" in the shadow of others.

The shape of the cross sections of the members has no direct effect on optical performance. However, sharp angled cross sections may be required to control scattered light.

7.6.2 Surface Property Requirements for Materials in Optical Path

All outer surfaces of structural elements in the field of view will be finished in optical black.

7.7 Safety Factors for Stresses

When designing SNAP structures, minimum safety factors to material yield and ultimate stresses, joint separation, or other structural failures will initially be assigned as recommended in the NASA standard *Structural Design and Test Factors of Safety for Spaceflight Hardware*[5]. The standard defines structural factors of safety for space structures as a function of the materials involved, the construction techniques, and the level of experimental verification.

7.8 Materials

7.8.1 Outgassing

All materials used in the construction of the telescope shall comply with NASA/GSFC basic outgassing criteria of <1% TML and <0.1% CVCM. Condensation of volatile materials on the mirror surfaces is the main concern. Note that the cold operating temperatures envisioned for SNAP will considerably reduce outgassing rates relative to levels established in ASTM tests. Also, baffle surfaces surrounding the mirrors will tend to operate cooler than the mirrors and act as cold traps. Materials with marginal CVCM may be vacuum-baked before use to reduce further outgassing.

7.8.2 Particulate Contamination

TBD

7.8.3 Other (magnetic, electrical, thermal conductivity, etc.)

TBD

8. References

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2. *Delta IV Payload Planners Guide,* doc. # MDC99H0065, The Boeing Company, Huntington Beach, CA, October 1999, available from `http://www.boeing.com/defense-space/space/delta/delta4/guide/index.htm`.
3. Private Fax Communication from M. Levi, LBNL, February 16, 2000.
4. General Environmental Verification Specification for STS & ELV Payloads, Subsystems, and Components (GEVS-SE), Rev. A, NASA/Goddard Space Flight Center, Greenbelt, MD 20771, June 1996.
5. Structural Design and Test Factors of Safety for Spaceflight Hardware, NASA Technical Standard NASA-STD-5001, NASA/Marshall Space Flight Center,
6. Gary Gonska, L3 Communications, private phone conversation, November 14, 2000.
7. Optical Telescope Assembly Definition and Requirements Document for the Supernova / Acceleration Probe (SNAP), Draft 0.1, U.C. Berlkeley and L.B.N.L, September 5, 2000.