HUBBLE SPACE TELESCOPE
WIDE FIELD CAMERA 3
CONTRACT END ITEM SPECIFICATION
(PART I)

April 7, 1999
Draft Version 2.00 (Two Channel WFC3)

This version is the first complete draft incorporating the Infrared Channel. It contains the CCD channel specifications essentially unchanged from the 15 March 1999 Version 1.00 Baseline Version.

The 1.00 Baseline version was a revision of the draft circulated within the WFC3 Science Oversight Committee (SOC), the HST Project, and to Ball Aerospace on 3 February. This draft was a revision of the 4 January draft following comments from all parties. The 4 January draft was a revision to the draft submitted to the Science Oversight Committee on 21 December 1998 and incorporated most of the changes suggested by the SOC prior to 3 January 1998.

N.B. Starting with the 15 March version we have explicitly excluded requirements requested and endorsed by SOC at the direction of the HST Flight Director. The CEI reflects those requirements (pertaining to the operation of the CCD channel) as being comparable to those planned or achieved for the ACS Science Instrument. The requirements which exceed this "ACS baseline" are being submitted simultaneously as Document Change Requests (DCRs).

Change bars on this draft reflect revisions to the 15 March 1999 draft.

0 ACRONYMS LIST

ACS	Advanced Camera for Surveys
AGN	Active Galactic Nuclei
ASCS	Aft Shroud Cooling System
C&DH	Command and Data Handler
CCD	Charge Coupled Device
CEI	Contract End Item
COSTAR	Corrective Optics Space Telescope Axial Replacement
COS	Cosmic Origins Spectrograph
EEE	Electrical, Electronic, and Electromechanical
EMC	Electromagnetic Compatibility
EVA	Extra-Vehicular Activity
FOC	Faint Object Camera
FOV	Field of View
FPA	Focal Plane Assembly
FWHM	Full Width at Half Maximum
GFE	Government Furnished Equipment
GHRS	Goddard High Resolution Spectrograph
GSFC	Goddard Space Flight Center
GSSS	Guide Star Selection System
HST	Hubble Space Telescope
ICD	Interface Control Document
IRD	Interface Requirements Document
ISM	Interstellar Medium
I&T	Integration and Test
JPL	Jet Propulsion Laboratory
LOS	Line of Sight
mm	Millimeter
MLI	Multi-Layer Insulation
MSFC	Marshall Space Flight Center
nm	Nanometer
NICMOS	Near Infrared Camera and Multi-Object Spectrometer
NSSC-1	NASA Standard Spacecraft Computer – Model 1
ORI	Orbital Replacement Unit
OTA	Optical Telescope Assembly
PASS	POCC Applications Software Support
PFU	Protoflight Unit
PIXEL	Picture Element
PSF	Point Spread Function
QE	Quantum Efficiency
RIU	Remote Interface Unit
RMS	Root Mean Square
ROM	Read Only Memory
SAA	South Atlantic Anomaly

SDF	Science Data Formatter
SI	Science Instrument
SI C&DH	Science Instrument Control and Data Handling
SIPE	Science Instrument Protective Enclosure
SMOV	Servicing Mission Orbital Verification
SNR	Signal to Noise Ratio
SOFA	Selectable Optical Filter Assembly
SSE	Space Support Equipment
SSM	Systems Support Module
STD	Standard
STIS	Space Telescope Imaging Spectrograph
STR	Space Telescope Requirements
STS	Space Transportation System
TBD	To Be Determined
TBR	To Be Reviewed
TV	Thermal Vacuum
UV	Ultra-Violet
WF/PC-I	Wide Field and Planetary Camera -I
WF/PC-II	Wide Field and Planetary Camera –II
WFPC2	Wide Field and Planetary Camera 2
WFC3	Wide Field Camera 3

WFC3 CEI PART I SPECIFICATION

1 SCOPE

This document establishes the scientific objectives, the scientific performance requirements, and the interface requirements for the Hubble Space Telescope (HST) Wide Field Camera 3 (WFC3) scientific instrument (SI). It provides a baseline for development of the Contract End Item (CEI) Specification Part II (STE-50).

1.1 STRATEGIC OBJECTIVES

The WFC3 shall be a general purpose facility instrument designed to provide HST with a high quality imaging capability until the end of the HST mission (nominally 2010). It shall take good advantage of the available HST image quality with improved throughput, and sampling compared to WFPC2. By replacing WFPC2, the WFC3 shall provide HST with CCD detectors which will have experienced significantly less on-orbit exposure to radiation than those in ACS or WFPC2 by the end of the HST mission. Further, with the inclusion of an Infrared (IR) Channel, the WFC3 will provide an enhanced near infrared imaging capability for HST beyond NICMOS. The WFC3 shall be designed for installation in a radial bay within the HST, during on-orbit extra-vehicular activity (EVA) during the fourth servicing mission (SM4), presently planned for 2003.

1.2 MAJOR SCIENTIFIC OBJECTIVES

Unlike previous HST science instruments, WFC3 is being developed as a facility class instrument. All previous HST instruments (with the partial exception of the FOC) were solicited together with scientific investigations and were developed under the leadership of a science team led by a principal investigator who was also responsible for the proposed scientific investigation. WFC3 is being developed by a team drawn from the HST project for the general benefit of the HST user community. As such, its scientific objectives are defined with less specificity than those of science instruments proposed by PI teams.

In place of the PI team, NASA has formed an Integrated Product Team (IPT) to develop WFC3. Further, a Science Oversight Committee (SOC) has been selected by NASA to provide the IPT with scientific guidance and to represent the views of the HST observer community to the WFC3 IPT and the HST Project.

WFC3 has four components to its scientific objectives. First, and foremost, it serves to provide redundancy for HST's visible light high resolution imaging capabilities from SM4 until the end of the HST mission (currently planned for 2010). Second, it offers the possibility of providing additional and complementary imaging capabilities to the ACS wide field channel including the provision of UV sensitivity (down to 200nm) over a wide field and a different but partially redundant set of filter elements. Third, the inclusion of an IR channel provide WFC3 with a high sensitivity imaging capability in the near Infrared providing HST with a second generation infrared instrument. Fourth, the WFC3 SOC and IPT are formulating a "Design Reference Mission" (DRM) of *representative* scientific programs to guide the WFC3 development process by providing both a vision of its potential scientific contributions and a metric by which to measure the relative importance of technical tradeoffs.

2 APPLICABLE DOCUMENTS

The following documents (shown in Tables 2-1, 2-2 and 2-3), most recent issue, form a part of this specification to the extent specified herein. In the event of a conflict between these documents and the Statement of Work, the Statement of Work shall take precedence. In the event of a conflict between these documents and other detailed contents of this specification, the detailed requirements herein shall take precedence except for the referenced Interface Control Documents (ICD's). All applicable documents and requirements specified in the following documents shall form a part of this specification by incorporation herein. Contractor specifications satisfying the intent of the following documents may be used in lieu of the specifically listed document upon review and approval by GSFC.

Table 2-1 Applicable Documents

1	Hubble Space Telescope (HST): Space Telescope Imaging Spectrograph (STIS), Near Infrared Camera and Multi-Object Spectrometer (NICMOS), Performance Assurance Requirements	STR-43
2	Second and Third Servicing Mission Orbital Replacement Instrument (ORI) Data Requirements Document	SCM-1030
3	Space Telescope Scientific Instruments to Scientific Instruments Control and Data Handling System Interface Control Document (SI to SI C&DH ICD)	ST-ICD-08
4	HST Level Interface Control Document, Radial Scientific Instruments to Optical Telescope Assembly and Support Systems Module (Radial SI to OTA and SSM)	ST-ICD-03
5	HST Servicing Mission Contamination Control Requirements	STR-29
6	Hubble Space Telescope Level 1 Requirements	NASA HQ OSSA
7	System Description and Design Data – Extra-vehicular Activity	NSTS 07700, Vol. XIV

Table 2-2 Reference Documents

1	The Hubble Space Telescope Wide Field Camera 3 Study Report, March 8, 1998	Study Report
2	HST Interface Control Document, Radial Scientific Instrument to Space Support Equipment	ST-ICD-83
3	Configuration Management	GMI 8040.1
4	HST Flight Projects Configuration Management Plan	SCM-1020
5	HST Science Instrument Test System (SITS) Specification	STE-27
6	ST Command List	SDM-1001
7	ST Instrumentation Program and Component List	SDM-1002

8	HST Constraints and Restrictions	SMO-1020
9	ST Mission Operations Functional Requirements Document	SMO-1000
10	HST Input to Project Data Base Interface Control Document	ST-ICD-26 Pt. 4

Table 2-3 Additional Required Documents

1	SI Calibration Procedures	AV-03
2	SI Pre-Launch Calibration Data	AV-04
3	Scientific and Performance Assessment and Calibration Report	AV-05
4	SI Command Lists	DM-01
5	SI Engineering Data List	DM-02
6	SI Command Development Handbook	DM-05
7	SI Science Data Format	DM-06
8	SI Engineering Telemetry Calibration List	DM-14
9	SI Operations Requirements Document	OP-01
10	Inputs to SMOV Plans & Proposals Calibration and SI Proposals	OP-03
11	Limited Life Matrix	PA-17
12	SI Systems Description and Users Handbook	SE-02
13	SI FSW Documentation	DM-03
14	SI Ground Software Documentation	DM-04
15	SI Software Test Plan	DM-07
16	SI Software Test Procedures and Reports	DM-08
17	Inputs to the CARD, OLD and CL (Critical Limits)	OP-04
18	Inputs to the SMIT	OP-05
19	Support for Operations Contingency Planning	OP-06
20	SM Aliveness and Functional Test Success Criteria	OP-07
21	Performance Verification Plan	AV-01
22	Configuration Management Plan	CM-01
23	Management Plan	MA-01
24	Systems Engineering Plan	SE-01
25	Requirements Verification Matrix	

3 SCIENCE INSTRUMENT DEFINITION

3.1 GENERAL DESCRIPTION

The WFC3 is one of five scientific instruments that will form part of the Focal Plane Assembly (FPA). The Optical Telescope Assembly (OTA) and Support systems Module (SSM) will provide the WFC3 with incoming light, target acquisition and, via the SI Control and Data Handling (C&DH) System, pointing control, data handling, communications, electrical power, and other services that are common to all SI' s.

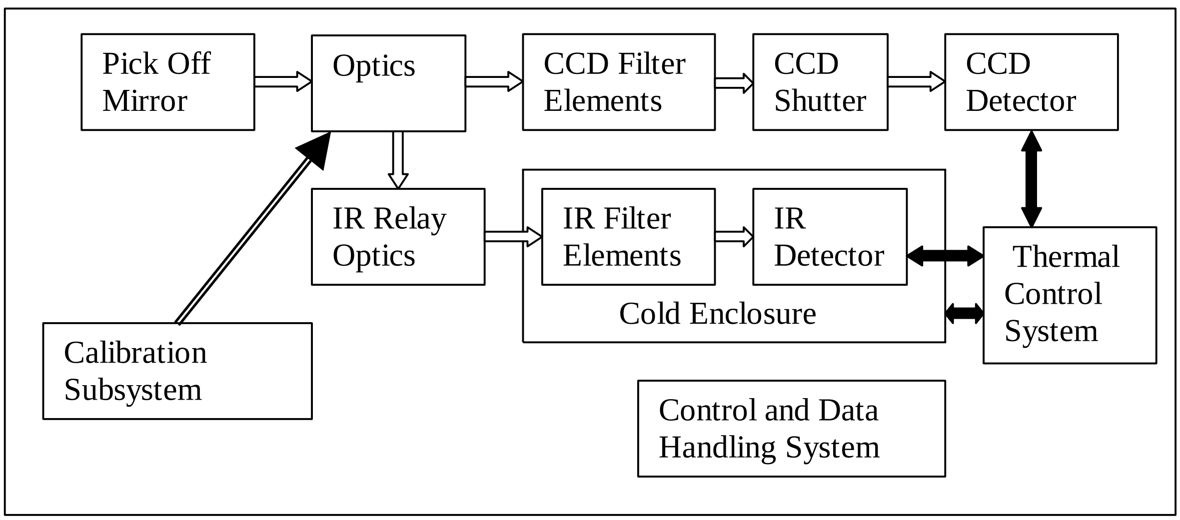
3.2 MISSION REQUIREMENTS

The WFC3 shall be designed, built, and tested for launch, orbital replacement, return to earth in the space shuttle, and operation in a nominal circular earth orbit at orbital altitudes from 398 km to 593 km at 28.8 degrees inclination. It shall be designed to be removed or installed into a radial bay of HST or the Radial Scientific Instrument Protective Enclosure (R-SIPE) in orbit by a suited astronaut performing EVA, or by technicians working in a one-g environment. The SI will be launched in the SIPE. The baseline bay assignment for the WFC3 shall be the radial bay replacing the WFPC2. The total SI shall consist of one integral package designed to survive handling and transportation loads as defined in ST-ICD-03.

[provision for attachment to external radiator is TBD. – JWM]

3.3 CONCEPTUAL VIEW OF WFC3

Figure 3-1



The diagram in the Figure above provides a conceptual view of the WFC3 science instrument. In WFC3 the Pick Off mirror is a fixed element which captures a portion of the HST focal plane and directs it into the WFC3. The "optics" sub-system provides correction for the HST OTA spherical aberration, brings WFC3 to a common focus with the other Science Instruments using a focus and alignment mechanism, and provides the required focal ratio at the CCD detector. The CCD filter elements are contained in a selectable mechanism and provide bandpass limitation and other science driven modifications to the incident light. The shutter mechanism provides a means of defining the duration of an exposure. The CCD detector converts photons into measured signal.

The optics train includes a "channel selection mechanism" to direct light into the IR relay optics which provide re-imaging to the required IR focal ratio. The IR Filter Elements are contained in a single wheel which provides bandpass limitation and other science driven modifications to the incident light. The IR detector converts photons into measured signal and also provides, by electronic gating, the means of defining the exposure duration. To achieve low internal background flux incident upon the IR detector, its surroundings including the IR filter elements and a "cold stop" are cooled.

WFC3 requires a thermal control subsystem to provide detector and environmental cooling to reduce internal dark current in both detectors. It also requires heating to control contamination and anneal radiation damage in the CCD detector. A calibration subsystem is required to provide simple internal illumination of the detectors for differential calibration. Finally, a control and data handling subsystem provides both control of each subsystem, telemetry, and handling of the science data from the detectors.

4 PERFORMANCE REQUIREMENTS

The WFC3 performance requirements shall be met after a suitable commissioning period, which shall not exceed servicing mission orbital verification (SMOV), during which focus and alignment settings and on-orbit operating parameters shall be determined. This period shall suffice to demonstrate that WFC3 conforms to all aspects of this Specification Document when combined with measurements and test results obtained during ground testing.

4.1 CHANNEL DESCRIPTIONS

The WFC3 provides two science channels. Both channels view the same region in the HST focal plane. This region is selected by an external pick-off mirror (POM).

4.1.1 CCD Channel

The CCD channel consists of an optical train capable of providing focus adjustment and correction for the HST OTA spherical aberration, a filter element selection mechanism, a shutter, and a CCD detector assembly. These are supported by a thermal control subsystem and also by control and data handling electronics subsystems. In general concept and functionality, this channel is patterned on the ACS WFC channel.

4.1.2 IR Channel

The IR Channel consists of a selection mechanism to divert light from the CCD channel (after the HST OTA spherical aberration), a filter element selection mechanism, and an IR detector assembly. These are supported by a thermal control subsystem and also by control and data handling electronics subsystems. This channel is cooled with TEC devices in a manner similar to the ACS WFC channel and it operated in a similar fashion to the NICMOS detectors.

4.2 SCIENCE PERFORMANCE METRICS

The WFC3 is intended as a facility science instrument will broad capabilities to support the community's needs for imaging science from HST. To capture a representative range of science capabilities, the DRM was constructed by the SOC and the Science IPT based upon science programs originated by SOC members.

The DRM is supported by an Exposure Time Calculator (ETC) developed by the Science IPT and a database estimating the observing time required to complete the DRM. One metric available to access the science performance of WFC3 is the relative time required to complete the DRM program.

4.3 OPTICAL PERFORMANCE

The optical performance of the WFC3 shall be met when provided with light from the HST in accordance with the optical parameters of ST-ICD-03. Correction for HST aberration shall be contained within the WFC3 including provision for on-orbit optical alignment capability.

4.3.1 Optical Design Parameters

4.3.1.1 Pixel Spacing.

4.3.1.1.1 CCD Channel

The nominal pixel center-to-center spacing of the CCD channel shall be 0.039 arc seconds.

4.3.1.1.2 IR Channel

The nominal pixel center-to-center spacing of the IR channel shall be 0.080 arc seconds

4.3.1.2 Field of View.

The unvignetted (>95% throughput) angular field of view projected onto the sky for the WFC3 shall be lie between 155 and 170 arc seconds on a side. Within these limits, it should be as large as practical without vignetting the FOVs of any axial bay science instrument(s).

4.3.1.3 Field of View Distortion.

The field of view shall be square within 5% (and also provide an allowance for any asymmetric gap(s) in the CCD mosaic not to exceed 2%) and oriented at a 45 degree angle (+/- 10 degrees) from the HST focal plane's V2-V3 coordinate system.

4.3.1.4 Wavefront Error.

The optical design shall provide essentially diffraction-limited performance over the FOV for λ > TBD. The Root Mean Square (RMS) wavefront error introduced by the combination of the HST optics and the WFC3 optical system in filter mode shall be less than $\lambda/11.75$ at 633nm with a goal of $\lambda/13.33$ at 633nm, at the center FOV position when used with an input wavefront which conforms to the following OTA characteristics:

Primary Conic Constant: K = -1.0139

Intervertex Distance: 4907.0100

These values shall apply over a square region (inscribed within the square field of view) whose corners are the center of the edges of the field of view, as a minimum.

4.3.1.4.1 Ultraviolet Wavefront Specification.

At λ < TBD (the near ultraviolet), the HST OTA introduces wavefront errors which significantly exceed diffraction limited performance. WFC3 shall not increase these errors by more than TBD percent corresponding to an instrumental wavefront error of no more than λ/TBD between 200nm and TBD.

4.3.1.4.2 Visible Wavefront Specification

4.3.1.4.3 Infrared Wavefront Specification

4.3.1.5 Geometric Distortion.

The magnitude and stability of the WFC3 geometric distortion shall be such that the relative positions of stellar images shall be determinable to within 0.2 pixel over the entire image by application of a correction function. This shall apply to point sources exposed to between 0.1 and 0.5 of detector linear full well and shall remain within tolerance over a period of at least 1 month.

4.3.1.6 Polarization Sensitivity.

The maximum value for induced polarization, assuming unpolarized incoming light, is 6.5 percent over the range 220 – 1000nm with a goal of < 5%.

[need IR specification – JWM]

4.3.2 Image Quality

4.3.2.1 CCD Channel Point Source Profile.

The WFC3 image quality requirement for the CCD channel in filter mode shall be the encircled energy as presented in Table 4-1. The image quality shall be achievable for the range of uncertainty in on-orbit conic constant and shall include all internal WFC3 effects due to thermal, mechanical, and optical contributions, but not those due to spacecraft jitter or guiding errors. Image quality is specified at both the center of the FOV and at the edge (where "corner" is taken to be 50 active pixels in both X and Y from the corners of the detector).

Table 4-1 Encircled Energy Requirements

Specification	Center of FOV	Corner of FOV
Core @ 633nm in 0.25 arc sec diameter	>75% Goal: >80%	>75% Goal: >80%
Core @ 250nm in 0.20 arc sec diameter	>75% Goal: >80%	>75% Goal: >80%

Wing @ 633 nm 0.5 arc sec radius	< TBD% peak	< TBD% peak
Wing @ 633 nm 1.0 arc sec radius	< TBD% peak	< TBD% peak
Wing @ 633 nm 2.0 arc sec radius	< TBD% peak	< TBD% peak
Wing @ 633 nm 3.0 arc sec radius	< TBD% peak	< TBD% peak
Wing @ 250 nm 0.5 arc sec radius	< TBD% peak	< TBD% peak
Wing @ 250nm 1.0 arc sec radius	< TBD% peak	< TBD% peak
Wing @ 250 nm 2.0 arc sec radius	< TBD% peak	< TBD% peak
Wing @ 250 nm 3.0 arc sec radius	< TBD% peak	< TBD% peak

4.3.2.2 IR Channel Point Source Profile.

The WFC3 image quality requirement for the IR channel in filter mode shall be the encircled energy as presented in Table 4-2. The image quality shall be achievable for the range of uncertainty in on-orbit conic constant and shall include all internal WFC3 effects due to thermal, mechanical, and optical contributions, but not those due to spacecraft jitter or guiding errors. Image quality is specified at both the center of the FOV and at the edge (where "corner" is taken to be 50 active pixels in both X and Y from the corners of the detector).

Table 4-2 Encircled Energy Requirements

Specification	Center of FOV	Corner of FOV
Core @ TBD nm in 0.25 arc sec diameter	>75% Goal: >80%	>75% Goal: >80%
Core @ TBD nm in 0.TBD arc sec diameter	>75% Goal: >80%	>75% Goal: >80%
Wing @ 633 nm 0.5 arc sec radius	< TBD% peak	< TBD% peak
Wing @ 633 nm 1.0 arc sec radius	< TBD% peak	< TBD% peak
Wing @ 633 nm 2.0 arc sec radius	< TBD% peak	< TBD% peak
Wing @ 633 nm 3.0 arc sec radius	< TBD% peak	< TBD% peak
Wing @ 250 nm 0.5 arc sec radius	< TBD% peak	< TBD% peak
Wing @ 250nm 1.0 arc sec radius	< TBD% peak	< TBD% peak
Wing @ 250 nm 2.0 arc sec radius	< TBD% peak	< TBD% peak
Wing @ 250 nm 3.0 arc sec radius	< TBD% peak	< TBD% peak

4.3.2.3 Uniformity of Image Quality.

At no position in the FOV may the image quality be worse than the "corner" specifications in Tables 4-1, and 4-2 for the appropriate channel. Further, a high degree of uniformity in the PSF is an important goal.

4.3.2.4 Image Jitter.

The internal image jitter introduced by the WFC3 itself shall be less than 3 milli-arcseconds (1 sigma) (with a goal of less than 1 milli-arcsecond) for any integration interval up to 1300 seconds. This requirement may be satisfied by design on the ground and verified on-orbit.

4.3.2.5 Image Drift.

4.3.2.5.1 CCD Channel

The image drift within the WFC3 CCD Channel shall be less than 10 milli-arcseconds peak-to-peak over two orbits relative to the FGS frame. The long-term stability shall allow consecutive exposures to be successfully co-added by exposure registration for elapsed periods of up to 24 hours without re-pointing the telescope or adjusting the WFC3. Registration to 0.25 pixels RMS is required for successful co-addition. This requirement may be satisfied by design on the ground and verified on-orbit.

4.3.2.5.2 IR Channel

The image drift within the WFC3 IR Channel shall be less than 20 milli-arcseconds peak-to-peak over two orbits relative to the FGS frame. The long-term stability shall allow consecutive exposures to be successfully co-added by exposure registration for elapsed periods of up to 24 hours without re-pointing the telescope or adjusting the WFC3. Registration to 0.25 pixels RMS is required for successful co-addition. This requirement may be satisfied by design on the ground and verified on-orbit.

4.3.2.6 Ghost Images.

Stray light due to reflected scatter in the optical train, including spectral defining elements, from a point source shall result in less than 0.1% of the total incident light within a discrete ghost image.

4.3.2.7 Large Angle Stray Light.

Stray light per pixel more than 30 arc seconds from a point source shall not exceed TBD % of the total brightness of the point source. This includes effects of the OTA.

4.4 SPECTRAL PERFORMANCE

4.4.1 Wavelength Range

4.4.1.1 CCD Channel

The nominal wavelength range of the WFC3 CCD channel shall be 200-1000nm, with special emphasis given to the 200-400nm range. Performance in this preferred spectral interval shall have priority in performing design trades.

4.4.1.2 IR Channel

The nominal wavelength range of the WFC3 IR channel shall be 850-1700nm, with a goal of 700 – 1900nm. Performance in the 1000 – 1600nm spectral interval shall have priority in performing design trades.

4.4.2 Optics Throughput.

4.4.2.1 CCD Channel Optics Throughput

The optics, exclusive of OTA, spectral Elements, and detector response, shall provide throughput exceeding the values in Table 4-3 for the CCD Channel

Table 4-3 CCD Channel Optics Throughput Requirements

Wavelength (microns)	Optics Throughput
0.18	TBD
0.2	0.59
0.25	0.59
0.3	0.61
0.35	0.60
0.4	0.60
0.45	0.62
0.5	0.62
0.55	0.62
0.6	0.62
0.7	0.60
0.8	0.52
0.9	0.59
1	0.72

4.4.2.2 IR Channel Optics Throughput

The optics, exclusive of OTA, spectral Elements, and detector response, shall provide throughput exceeding the values in Table 4-4 for the IR Channel

Table 4-4 IR Channel Optics Throughput Requirements

Wavelength (microns)	Optics Throughput
0.60	TBD
0.70	TBD

0.80	TBD
0.90	TBD
1.00	TBD
1.10	TBD
1.20	TBD
1.30	TBD
1.40	TBD
1.50	TBD
1.60	TBD
1.70	TBD
1.80	TBD
1.90	TBD

4.4.3 Spectral Range Stability

Photometric capabilities are an important aspect of the WFC3 scientific goals. Stability in throughput over the entire spectral range is essential to these goals. Table 4-3 establishes requirements for throughput stability. These specifications are for any one month period (after the first 3 months in orbit). These include all components including detectors after calibration.

In addition, all variations in excess of 3% per year shall be recoverable by decontamination procedure(s).

Table 4-3 Throughput Stability Requirements

Wavelength Range	Throughput Stability
200 – 300 nm	<5 % per month (<1% goal)
300 – 400 nm	<3% per month (<1 % goal)
400 – 600 nm	<1% per month (<0.5% goal)
600 – 1000 nm	<1% per month (<0.5% goal)
1000 – 2000nm	<1% per month (<0.5% goal)

4.4.4 Optical Coatings

4.4.4.1 CCD Channel Optical Coatings

Optical coatings on optics and filter elements within the CCD Channel shall be designed to maximize efficiency with an emphasis on the 200 – 400nm wavelength region. No individual coating surface shall decrease in throughput by more than 0.6 percent by delivery or 1.0 percent over 5 years.

4.4.4.2 IR Channel Optical Coatings

Optical coatings on optics unique to the IR Channel shall be designed to minimize emission of thermal radiation between 1.4 and 2.0 microns. Consistent with this requirement, high reflectivity is desired. Further, no individual coating surface shall decrease in throughput by more than 0.6 percent by delivery or 1.0 percent over 5 years.

4.4.5 CCD Channel Spectral Components

4.4.5.1 Number of Spectral Elements

The WFC3 CCD channel shall contain at least 48 selectable spectral defining elements. As a minimum, the spectral elements defined in Table 4-5 will be included.

4.4.5.2 Types of Spectral Elements

Provision to support spectral filters, polarizers, prisms, grisms, and ramp filters must be provided in the CCD channel. These spectral elements must be located in the unaberrated beam.

4.4.5.3 Spectral Elements Selection Mechanism

The mechanism to support spectral element selection for the CCD channel shall be the refurbished WF/PC-1 SOFA mechanism.

Table 4-4 WFC3 CCD Channel Spectral Elements

TBD	TBD
TBD	TBD

4.4.6 IR Channel Spectral Components

4.4.6.1 Number of Spectral Elements

The WFC3 IR channel shall contain at least 10 selectable spectral defining elements (with a goal of 20 elements). As a minimum, the spectral elements defined in Table 4-6 will be included.

4.4.6.2 Types of Spectral Elements

Provision to support spectral filters, polarizers, prisms, and grisms in the IR channel must be provided. These spectral elements must be located in the unaberrated beam.

4.4.6.3 IR Spectral Elements Selection Mechanism

The IR spectral elements selection mechanism must be capable of selecting any element in less than 60 seconds. Operational lifetime must be consistent with both the DRM and the requirement for at least three motions (any element position to any other element position) per orbit over the design life of WFC3. The IR spectral element selection mechanism must provide a means of fully blocking the path of light to the detector.

Table 4-6 WFC3 IR Channel Spectral Elements

TBD	TBD
TBD	TBD

4.4.7 Channel Selection Mechanism Spectral Components

4.4.7.1 Number of Spectral Elements

The WFC3 channel selection mechanism shall contain at least 4 selectable spectral defining components. As a minimum, the spectral elements defined in Table 4-7 will be included.

4.4.7.2 Types of Spectral Elements

Provision to support transmission to the CCD channel, reflection to the IR channel, and at least two beam splitting filters must be provided.

4.4.7.3 Spectral Elements Selection Mechanism

The channel selection mechanism must be capable of selecting any element in less than 60 seconds. Operational lifetime must be consistent with both the DRM and the requirement for at least three motions (any element position to any other element position) per orbit over the design life of WFC3.

Table 4-7 WFC3 Channel Selection Mechanism Spectral Elements

Clear (UV optimized)	Mirror (IR optimized)
TBD—beamsplitter	TBD—beamsplitter

4.5 CCD CHANNEL SHUTTER PERFORMANCE

4.5.1 Range of Exposure Times

WFC3 CCD Channel shall be equipped with a shutter capable of providing timed exposures from 0.10 seconds to >6000 seconds. Selectable integration times shall be supported in increments of 0.10 seconds from a minimum of 0.1 sec to at least 100 minutes. For exposures longer than 10 seconds these may be supported in increments of 1 second. For exposures longer than 100 seconds these may be supported in increments of 10 seconds.

4.5.2 Calibration of CCD Channel Shutter Operation

The CCD Channel shutter shall be repeatable to better than 0.01 seconds. For exposures greater than 1.0 seconds, shading (uncorrected) shall be less than 1%. [TBR —JWM].

4.6 CCD CHANNEL DETECTOR REQUIREMENTS

4.6.1 CCD Orientation (TBR)

The orientation of the WFC3 CCD array is driven by the FOV of the pickoff mirror. The orientation of the optical FOV is specified in 4.3.1.3.

4.6.2 CCD QE Sensitivity

The WFC3 CCD detector sensitivity shall be optimized for the spectral interval 200-400nm and meet the following QE requirements, specified at several key wavelengths in Table 4-5. QEmin is to be taken as the minimum allowable monochromatic detector QE within the specified wavelength interval (with the exception of the 200-300nm region where it shall be taken as the average QE within that interval). These requirements apply to a detector without window and operating at –83C.

Table 4-5 CCD Detector QE Requirements

Wavelength range	QE min	QE Goal
200–300nm	30%	65%
300-400nm	40%	65%
400-600nm	50%	80%
600-800nm	50%	70%
800-950nm	30%	40%

[TBR: these were obtained from the SITe blue HRC device for the QEmin values and the best Lesser (blue or red detectors for the "QE Goal" values–JWM]

The selection of anti-reflective coatings applied to the CCD detector shall emphasize the 200-400nm range.

4.6.3 CCD Detector Readout Noise

The CCD detector read noise shall not exceed 4.0 electrons per pixel (with a goal of 3 electrons) at 30,000 pixels/second readout rate.

4.6.4 CCD Detector Dark Current

The detector dark current shall not exceed 10 electrons per pixel per hour at –90C.

4.6.5 CCD Detector Internal Background

Any detector emission or emission from the detector assembly windows (e.g. due to SAA passage) shall not exceed 10 electrons per pixel per hour.

4.6.6 CCD Detector Correlated Noise.

Noise in any image due to electrical interference shall be limited such that a one dimensional Fourier analysis of the pixel readouts contains no spectral components having more than 50 percent (TBR) higher power density than the background random noise spectrum.

4.6.7 CCD Detector Full Well

The Full Well capacity shall be a minimum of 50,000 electrons per pixel with a goal of 85,000 electrons.

4.6.8 CCD Detector Linearity and Dynamic Range

The response shall be linear with input signal to <5% (correctable to <0.3%) over the range 100 to 50,000 electrons and shall be independent of exposure time.

4.6.9 CCD Detector Charge Transfer Efficiency and resistance to radiation damage

CTE testing shall be performed both with radioactive (on the ground) and light sources. Performance requirements are specified in Table 4-6. The required charge losses are across 2048 pixels under zero background conditions (i.e. independent of the number of sources on the detector).

Table 4-6 CCD Detector CTE Requirements

	At Launch		After 5 Years	
Signal Level	Uncorrected loss	Correctable to	Uncorrected loss	Correctable to
300 e-/pixel	<3%	1%	<10%	2%
3,000 e-/pixel	<2%	<1%	<5%	1%
30,000 e-/pixel	<1%	<1%	<3%	<1%
1620 e-/pixel	.99999/pixel		.99995/pixel (at 2.5 years)	

In addition, ground testing shall characterize the performance at 50 and 100 electrons per pixel signal levels.

4.6.10 CCD Detector QE stability

Absolute QE stability (peak-to-peak) /hour shall be better than +/- 0.5%, and the QE stability (peak-to-peak) /month shall be better than +/- 1% (2% shortwards of 300 nm). Pixel-to-pixel stability (1σ)/hour shall be better than 0.2%. It shall be satisfactory to demonstrate short term stability requirements during ground test.

4.6.11 CCD Detector Flat Field Properties

4.6.11.1 CCD Detector Uniformity

The CCD detector shall be correctable to a uniform gain per pixel to <2% at all wavelengths and <1% between 400nm and 850nm (goal less than 0.5%). No more than 5% of all pixels shall have response outside the range of 90 – 110% of the mean response. Goal to have <1% of pixels outside range of 95 – 105%.

4.6.11.2 CCD Detector Low Spatial Frequency Flat Field Structure

Large scale flat field non-uniformities shall not exceed 3% peak-to-peak including the WFC3 optical system. The large scale non-unformity shall be correctable to <2%.

4.6.11.3 CCD Detector Non-functional Pixels

No more than 1% of the pixels may be non-functional. Non-functional pixels include dead pixels, hot pixels (exceeding 100 time the mean dark current or 0.1 e-/s/pixel which ever is larger), pixels with uncorrected QE's less than 50% or more than 200% of the mean QE.

4.6.11.4 CCD Detector Flat Field Stability

The difference between two flat fields taken 60 days apart using the same instrument configuration shall not exceed 1% rms (0.5% goal). Further, no more than 5% of the field of view shall exceed 5% variation.

4.6.12 CCD Detector Overlight Response

The CCD detector array shall not be harmed by exposure to any light levels (other than direct solar radiation). Exposures of less than 2 times full well should not result in blooming and exposures of less than 100 times full well may only bloom in the detector columns containing the overlight pixels. Residual images from 100 times full well overlight conditions shall not exceed 1 electron per second per pixel after 96 minutes.

4.6.13 CCD Detector Pixel Response Function

The CCD detector shall be backside illuminated and shall have inter-pixel gaps which do not exceed TBD percent of the pixel width (where gaps are defined to be regions with less than 50% of the response at the pixel centers). Pixel to pixel cross talk shall be sufficiently small that 90% of the energy from a 5 micron diameter spot centered on a pixel shall be detected within that pixel. It is expected that backside illuminated detectors will meet this specification. It shall be satisfactory to demonstrate compliance with measurements on detectors from the same lot.

4.6.14 CCD Detector Bias Stability

The detector bias (zero) level over a single row shall be stable during array readout to at least 2 electrons RMS. The bias level for the entire array shall be correctable to at least 1 electron RMS.

4.6.15 CCD Detector Cosmic Ray Susceptibility

The median energy deposited per charged particle event shall not exceed 2000 electrons. The median number of pixels containing more than 5% of the total event energy shall not exceed 6. These values correspond to a detector effective thickness of approximately 25 microns.

4.7 CCD Detector Thermal Control

[NOTE: all 4.7 values should be considered TBD pending engineering study.]

4.7.1 CCD Detector Cold Operation

4.7.1.1 CCD Operating Temperatures

The nominal operating temperature for the WFC3 CCD is -83°C (with a goal of –90C). Provision for cooling using thermal electric coolers and rejection of waste heat via the WFC3 external radiation shall be provided. . Indefinite operation at cold set-points is required.

4.7.1.2 CCD Temperature Regulation

Regulation via set-points at intervals no greater than 5 degree C shall be provided. Regulation sufficient to meet the QE stability requirement (4.6.10) over 24 hours is required.

4.7.1.3 CCD Temperature Measurement

Absolute temperature measurement to 1 degree C is required.

4.7.2 CCD Detector Warm Operation

4.7.2.1 Range of CCD Detector Warm Operating Temperatures

The thermal control system shall be designed to permit periodic warming of the CCD detector to at least -5 degrees C (with a goal of +5 degrees C). Operation at warm temperatures is necessary to permit annealing hot or warm pixels.

Operation of the WFC3 CCD detector at its warmest set-point for at least 48 hours shall be permitted.

4.7.3 CCD Channel Thermal Transition Time

It shall be possible to transition from nominal operate temperature to anneal temperature and return to operating temperature in less than 24 hours exclusive of the time spent at the warm (anneal) temperature.

4.7.4 CCD Channel Safe State Operation

Operation at to maintain the CCD detector external window above the ambient temperature in the instrument enclosure is necessary to provide a contamination safe state for instrument hold.

4.8 IR CHANNEL DETECTOR REQUIREMENTS

4.8.1 Orientation (TBR)

The orientation of the WFC3 IR array is driven by the FOV of the pickoff mirror. The orientation of the optical FOV is specified in 4.3.1.3.

4.8.2 IR Detector QE Sensitivity

The WFC3 IR detector sensitivity meet the following QE requirements, specified at several key wavelengths in Table 4-5. QEmin is to be taken as the minimum allowable monochromatic detector QE within the specified wavelength interval (with the exception of the 600-800nm and 1800-1900nm where these should be the average values). These requirements apply to a detector without window and operating at 150K.

Table 4-5 IR Detector QE Requirements

Wavelength range	QE min	QE Goal
600-800nm		
800-1000nm		
1000-1200nm		
1200-1400nm		
1400-1600nm		
1600-1800nm		
1800-1900nm		
1900-10000nm	0%	0%

4.8.3 IR Detector Readout Noise

The single read pair IR detector read noise shall not exceed 15.0 electrons per pixel (with a goal of 10 electrons per pixel) at TBD pixels/second readout rate. The achievable readout noise from a sequence of 10 non-destructive readouts shall not exceed 10 electronics per pixel (with a goal of 7 electrons per pixel) at the same readout rate.

4.8.4 IR Detector Dark Current and Internal Background

The combined IR detector dark current and signal from radiation generated internal to the WFC3 and HST shall not exceed 0.4 electrons per pixel per second at the nominal operating temperatures with a goal of 0.1 electrons per pixel per second. This specification does not include the emission contribution from the amplifiers on the detector.

[***we need to review this carefully. This is reasonable for the detector and probably the interior of the WFC3…but a calculation of the OTA contribution and, by implication, the effectiveness of the cold stop, is required.—JWM]

4.8.5 IR Detector Amplifier Emission ("Amp Glow") Contribution

The additional signal from IR detector amplifier emission beyond the limits in 4.8.4 shall not exceed TBD electrons at the detector center and TBD electrons for more than 5% of the pixels on the detector.

4.8.6 IR Detector Correlated Noise.

Noise in any image due to electrical interference shall be limited such that a one dimensional Fourier analysis of the pixel readouts contains no spectral components having more than 50 percent (TBR) higher power density than the background random noise spectrum.

4.8.7 IR Detector Full Well

The Full Well capacity shall be a minimum of TBD electrons per pixel with a goal of TBD electrons.

4.8.8 IR Detector Linearity and Dynamic Range

The response shall be linear with input signal to <5% (correctable to <0.3%) over the range 100 to TBD electrons and shall be independent of exposure time.

4.8.9 IR Detector Resistance to Radiation Damage

TBD. (also spec for SAA afterglow!)

4.8.10 IR Detector QE stability

Absolute QE stability (peak-to-peak) /hour shall be better than +/- 0.5%, and the QE stability (peak-to-peak) /month shall be better than +/- 1%. Pixel-to-pixel stability (1σ)/hour shall be better than 0.2%. It shall be satisfactory to demonstrate short-term stability requirements during ground test.

4.8.11 IR Detector Flat Field Properties

4.8.11.1 Detector Uniformity

The IR detector shall be correctable to a uniform gain per pixel to <2% at all usable wavelengths and <1% between 1000-1800nm (goal less than 0.5%). No more than 5% of all pixels shall have response outside the range of 50 – 200% of the mean response. Goal to have <1% of pixels outside range of 95 – 105%.***TBR***

4.8.11.2 IR Channel Low Spatial Frequency Flat Field Structure

Large-scale flat field non-uniformities shall be correctable to <2%.

4.8.11.3 IR Detector Non-functional Pixels

No more than TBD% of the pixels may be non-functional. Non-functional pixels include dead pixels, hot pixels (exceeding 100 time the mean dark current), pixels with uncorrected QE's less than 25% or more than 400% of the mean QE.

4.8.11.4 IR Detector Flat Field Stability

The difference between two flat fields taken 60 days apart using the same instrument configuration shall not exceed 1% rms (0.5% goal). Further, no more than 5% of the field of view shall exceed 5% variation.

4.8.12 IR Detector Overlight Response

The IR detector shall not be harmed by exposure to any light levels (other than direct solar radiation). Exposures of less than 2 times full well should not result in blooming and exposures of less than 100 times full well may only bloom to a radius of TBD pixels. Residual images from 100 times full well over-light conditions shall not exceed 1 electron per second per pixel after 96 minutes.

4.8.13 IR Detector Pixel Response Function

The IR detector inter-pixel gaps shall not exceed TBD percent of the pixel width (where gaps are defined to be regions with less than 50% of the response at the pixel centers). Pixel to pixel cross talk shall be sufficiently small that 90% of the energy from a 5 micron diameter spot centered on a pixel shall be detected within that pixel. It shall be satisfactory to demonstrate compliance with measurements on detectors from the same lot.

4.8.14 IR Detector Bias Stability

The detector bias (zero) level over a single quadrant shall be correctable to better than 3 electrons RMS with a goal of 1 electron RMS. The difference in bias level between any pair of readouts in an exposure shall be determinable to less than 3 electrons with a goal of 1 electron.

4.8.15 IR Detector Cosmic Ray Susceptibility

The median energy deposited per charged particle event shall not exceed TBD electrons.

TBD: spec on SAA afterglow goes here

4.9 IR Detector Thermal Control

[NOTE: all 4.9 values should be considered TBD pending engineering study.]

4.9.1 Cold Operation

4.9.1.1 Operating Temperatures

The nominal operating temperature for the WFC3 CCD is 150°K. Provision for cooling using thermal electric coolers and rejection of waste heat via the WFC3 external radiation (or other radiators) shall be provided. . Indefinite operation at cold set-points is required.

4.9.1.2 Temperature Regulation

Regulation via set-points at intervals no greater than 2 degrees C shall be provided. Regulation sufficient to meet the QE stability requirement (4.6.10) over 24 hours is required.

4.9.1.3 Temperature Measurement

Absolute temperature measurement to 1 degree C is required.

4.9.2 Warm Operation

4.9.2.1 Range of Warm Operating Temperatures

The thermal control system shall be designed to permit periodic warming of the IR detector to at least -30 degrees C (with a goal of +5 degrees C). Operation at warm temperatures is desired to remove potential contamination and to offset radiation damage.

Operation of the IR detector at its warmest set-point for at least 48 hours shall be permitted.

4.9.3 IR Thermal Transition Time

It shall be possible to transition between the nominal operate and warm temperatures in less than 24 hours.

4.9.4 Safe State Operation

Operation at to maintain the IR detector external window above the ambient temperature in the instrument enclosure is necessary to provide a contamination safe state for instrument hold. --*** this requirement is TBD for the IR detector—JWM

4.10 OPERATIONAL REQUIREMENTS

4.10.1 Observation Modes

The WFC3 shall support the following observation modes:

[This section needs revision to support IR channel parallel and sequential operations.—JWM]

4.10.1.1 Observe Modes

4.10.1.1.1 CCD Observe Mode

This shall be the standard science (and external calibration) data taking mode. The exposure time, the state of the shutter (active or closed), and the filter element selected must be specified. Bias exposures (zero exposure time) shall result in no shutter movement.

This shall be equivalent to the ACS/WFC IMAGE mode.

4.10.1.1.2 IR Observe Mode

This shall be the standard science (and external calibration) data taking mode. A sequence of up to 9 monotonically increasing exposure times and the filter element selected must be specified. The exposure sequence consists on an initial detector reset, a detector readout (zero read), and then 1 or more additional readouts at times subsequent to the zero read as specified in the exposure command.

This shall be equivalent to the NICMOS MULTACCUM mode.

4.10.1.2 Internal Calibration Lamp Mode

Observe mode exposures with the internal calibration lamp activated shall be supported. This mode provides control of the lamp sub-system (see 4.11).

4.10.1.3 Anneal Mode

Performs a pre-determined warm-up sequence, hold at a warm temperature set-point, and then returns WFC3 to operating temperature.

4.10.1.4 Operate Mode

Maintains WFC3 in a state ready to take data (i.e. transition to OBSERVE mode). This should be suitable for passage(s) through the SAA.

4.10.1.5 Hold Mode

Places the WFC3 is a state suitable for longer term inactivity than OPERATE mode.

4.10.1.6 Safe Mode

Places WFC3 in a safe state where minimal NSSC-1 and ground monitoring is required. Places WFC3 in a safe state with the maximum contamination protection and thermal safety. Primary goal is to minimize spacecraft power consumption.

4.10.2 CCD Detector Operation Requirements

4.10.2.1 Detector Readout

For a single 2048 x 4096 CCD chip, readout may be made through either one or two amplifiers to one or two independent sectors of memory, respectively. For a monolithic 4096 x 4096 detector, readout may be made from any of four amplifiers. Maximum read-out time for either array with four amplifier operation shall be two minutes or less.

4.10.2.2 Low Noise Readout Mode
TBD

4.10.2.3 Subarray Readout Capability

TBD

4.10.2.4 Selectable Gain Settings

Four gains shall be selectable in increments from 1, 2, 4, and 8 electrons /bit.

4.10.2.5 On chip Binning

TBD

4.10.2.6 Non-integrating Requirements

Basic flush operations shall be provided to condition the CCD. Continuous flushing shall be the normal mode while not integrating or reading out, except in Safe Mode (TBR – what about HOLD mode?).

4.10.2.7 Readout electronics requirements

Readout electronics shall have the capability to reduce the VDD bias to ground potential to eliminate amplifier glow.

Clock phasing and critical voltages shall be variable and selectable to compensate for any possible on-orbit radiation damage.

4.10.2.8 Overscan Data requirement

Overscan shall be provided to determine line-to-line variations.

4.10.3 IR Detector Operation Requirements

4.10.3.1 Detector Readout

IR detector array readout shall be made through all 4 quadrants. Maximum read-out time shall be TBD seconds or less for a single readout. Provision for up to ten non-destructive readouts shall be made within a single exposure.

4.10.3.2 Subarray Readout Capability

TBD

4.10.3.3 Selectable Gain Settings

Four gains shall be selectable in increments from 2, 4, 8, and 16 electrons /bit.

4.10.3.4 Non-integrating Requirements

Basic flush operations shall be provided to condition the IR detector. Continuous flushing shall be the normal mode while not integrating or reading out, except in Safe Mode (TBR – what about HOLD mode?).

4.10.3.5 Readout electronics requirements

Readout electronics shall provide a bias reference voltage and/or provide a differential signal referenced to that voltage to ensure a well defined and stable zero-point for the data.

Clock phasing and critical voltages shall be variable and selectable to compensate for any possible on-orbit radiation damage or deterioration in the electronics.

4.10.4 Parallel Operations

4.10.4.1 External Parallel Operations

WFC3 shall support parallel operation with other science instruments on HST within the constraints of the HST on-board data processing system. Provision to store 2 uncompressed images in internal memory to minimize scheduling demands on the SDF shall be made. This requirement shall, as a goal, extend to the operation of the WFC3 internal calibration lamp subsystem.

4.10.4.2 Internal Parallel Operations

TBD

4.10.5 CCD Preflash Capability

TBD

4.11 CALIBRATION

4.11.1 Calibration Subsystem Purpose

The WFC3 shall contain an on-board optical stimulation/calibration capability. This capability shall provide illumination of the entire field of both the CCD and IR detectors with light which passes through their filter assemblies. This calibration sub-system is intended to provide a calibration monitoring capability and a means of assessing correct operation of key instrument sub-systems (e.g. filter selection, shutter, detector gain, linearity, and cosmetics). Also, it provides a path to "bootstrap" the ground calibrations onto an initial set of on-orbit calibrations.

4.11.2 Calibration Subsystem Spatial Uniformity

Illumination shall be uniform to better than a factor of 2 over the field of view.

4.11.3 Calibration Subsystem Temporal Stability

Stability (<1%) per pixel is required over 1 hour and <5% over 1 year. Lamp color temperature stability (over 1 hour) and repeatability (over 1 year) to 50 degrees K (TBR—JWM).

4.11.4 Wavelength Coverage and Spectral Requirements

The calibration subsystem shall provide usable flux from 200 – 2000nm with no more than 20% out of band flux in any spectral element. The calibration subsystem shall provide both red (cool) and a blue (hot) continuum sources.

5 DESIGN REQUIREMENTS

5.1 SYSTEM

5.1.1 System Interfaces

The WFC3 shall meet all interface requirements specified in the Applicable Documents, including requirements to interface with the OTA/SSM and the SI C&DH as defined in ST-ICD-03 and ST-ICD-08, respectively.

5.1.2 Useful Life

The WFC3 shall be designed for a minimum of five years (goal of 8 years) on-orbit operating life and a minimum of seven years calendar life. Calendar life is defined as the period during which an item can retain its desired performance and reliability characteristics while in storage or installed, operating or non-operating, before being refurbished or re-certified.

5.1.3 Single Point Failure

The WFC3 shall be designed such that no single failure (other than the loss of the POM) shall violate the following for either channel:

5.1.3.1 Unvignetted Throughput

For any single failure, unvignetted throughput shall be available.

5.1.3.2 Fraction of Data

For any single failure, the majority of the data shall be unaffected.

For any single failure (except failure of the CCD shutters or thermo-electric coolers), data from at least half of the data field in each channel shall be unaffected.

5.1.3.3 Redundancy

Provision shall be taken to minimize the probability that redundant items will fail due to a single cause or event and to isolate redundant critical items to the maximum extent possible.

5.1.3.4 Impact on HST

The WFC3 shall have no single point failure that affects recovery of the HST. No single point failure shall result in total loss of command, engineering or scientific capability. No single point failure shall simultaneously blow both the primary and redundant bus fuses.

5.1.4 Fail-Safe and Redundancy

5.1.4.1 General Mechanism Redundancy

Mechanisms shall contain redundant drive motors in the event of failure.

5.1.4.2 CCD Channel Shutter

The CCD Channel shutter shall consist either of two blades, each of which is driven by independent motors or a single blade driven by a redundant motor.

5.1.4.3 Selectable Optical Filter Assembly

The SOFA shall contain redundant drive motors for each filter wheel contained within.

5.1.4.4 IR Optical Element Selection Mechanism

The IR optical element selection mechanism (filter wheel) shall have a redundant drive motor.

5.1.4.5 Channel Selection Mechanism

The channel selection mechanism shall have a redundant drive motor.

5.1.4.6 Corrective Optics Alignment and Focus Mechanism

The corrector mechanism shall contain redundant drive motors.

5.1.5 Commonality

The WFC3 shall make optimal use of hardware and software design commonality with the Wide Field and Planetary Camera 2 (WFPC2), the Advanced Camera for Surveys (ACS), the Space Telescope Imaging Spectrograph (STIS), and the Near Infrared Camera and Multi-Object Spectrometer (NICMOS) to the maximum extent practicable, consistent with the WFC3 scientific objectives.

5.2 OPTICAL

5.2.1 Optical Interfaces

The WFC3 shall meet the performance requirements of this specification when presented with optical input from HST that is in accordance with ST-ICD-03.

5.2.2 Optical Design

The WFC3 shall correct for the as-built HST spherical aberration, as well as off-axis aberrations. Focus control shall be provided to compensate for uncertainties in location of the SI with respect to the HST focus after insertion in orbit and to compensate for uncertainties in the definition of HST focus.

5.3 MECHANICAL AND STRUCTURAL

5.3.1 Mechanical Interfaces

The WFC3 shall meet all mechanical interface requirements specified in the Applicable Documents, including requirements to interface with the OTA/SSM and the Remote Interface Units (RIU's) as defined in ST-ICD-03 and ST-ICD-08, respectively.

5.3.2 Mechanical Interchangeability

The WFC3 shall be designed for mechanical compatibility and mounting into the specific WFPC-II radial instrument bay. The WFC3 design will include the pick-off mirror assembly necessary to divert the OTA beam into the radial bay science instrument.

5.3.3 Loads

The WFC3 shall operate within specification after exposure to ground, launch, ascent, in-orbit, and landing loads as specified in ST-ICD-03.

5.3.4 Modal Characteristics

The WFC3 shall meet the stiffness and modal frequency requirements specified in ST-ICD-03.

5.3.5 Mass Properties

5.3.5.1 Maximum Allowable Mass Limits

The maximum allowable weight shall be TBD lbs(without GFE hardware) and TBDlbs(with GFE hardware). (This allowable weight requirement shall be determined by the variation from the specified center of gravity location as per ST-ICD-03).

5.3.5.2 RIU's

Two SI C&DH Remote Interface Units (RIU's) shall be included in the weight requirement. Other Government Furnished Equipment (GFE), as defined in ST-ICD-03, are not included in the weight budget; however, they shall be included in the WFC3 mass properties.

5.3.5.3 Center of Gravity and Moments

The center of gravity and moments of inertia of the complete SI end item shall be determined to the accuracies specified in ST-ICD-03.

5.3.6 Envelope

The WFC3 outer dimensions shall be as specified in ST-ICD-03. The Remote Interface Units (RIU's) shall be mounted within the envelope dimensions specified in ST-ICD-03.

5.3.7 Mounting and Alignment

The WFC3 shall be designed for installation into, and safe removal from, the Focal Plane Assembly per ST-ICD-03. The WFC3 will be transported to orbit in a Scientific Instrument Protective Enclosure (SIPE) (ST-ICD-91). The WFC3 design shall not preclude installation into, and safe removal from, the SIPE. The GFE latching mechanisms and crew aids shall be installed prior to completion of the WFC3.

5.3.8 Venting

The WFC3 shall meet the venting requirements of ST-ICD-03. The venting shall be adequate to permit sufficient outgassing to ensure normal instrument operating conditions in orbit during SMOV. Adequate structural margins shall be maintained to ensure protection during ascent and descent. Designs shall minimize flow over optical surfaces and shall ensure that the SI is not contaminated during test, ascent, or return in the SIPE. Provision shall also be made to permit purging of the SI when fully assembled. Vent port and entrance aperture covers shall also be provided.

5.3.9 Ground Refurbishment and Maintenance

The WFC3 design shall provide ease of ground maintenance and ground replacement of a subsystem or component if necessary.

5.3.10 Orbital Replacement

The WFC3 shall be designed for in-orbit installation into, and removal from, HST or the SIPE by suited astronauts performing Extravehicular Activity (EVA). EVA handrails shall be provided assist in handling and inserting the WFC3 into the designated radial bay on HST. The design and implementation shall be consistent with that used for WFPC2 on SM1 and shall incorporate any lessons learned from that Servicing Mission.

5.3.11 SIPE Interface

The WFC3 will be transported to the HST as an ORU enclosed in the SIPE. The SIPE’s mechanical interface with the WFC3 will be in accordance with and satisfy the requirements of ST-ICD-83.

5.3.12 Pickoff Mirror Cover

A pickoff mirror cover shall be designed, built, tested and delivered as part of the instrument. The mirror cover will protect the mirror during EVA. The mirror cover will be installed on the instrument prior to flight and will be red-tagged for removal by the astronaut immediately prior to insertion into the radial instrument bay on the HST.

5.3.13 CCD Detector Replacement Capability

The WFC3 shall be designed to allow replacement of the WFC CCD detector package at any stage of instrument assembly prior to launch without significant de-integration.

5.4 THERMAL

5.4.1 Thermal Interfaces

The WFC3 shall meet the thermal interface requirements of ST-ICD-03.

5.4.2 Thermal Design

5.4.2.1 Overall Goals

A passive thermal design shall be used, as far as practical, to achieve WFC3 temperature control and stability.

5.4.2.2 Multi-Layer Insulation

All MLI shall be protected to resist abrasion and crushing.

5.4.2.3 Thermal Control

The thermal control will ensure that the instrument remains within acceptable operational temperature limits for all parts of the HST mission in which the HST is within ICD limits. Short-term temperature changes (up to 1 hour) under any HST operation condition shall not adversely impact the WFC3 performance during an observation. Long-term effects (greater that 24 hours) shall not result in permanent misalignment of the WFC3.

5.4.2.4 Ground Operation

All heat pipes used in the WFC3 will be located such that the detector may be operated and tested on the ground.

5.4.2.5 Servicing Mission Specific Requirements

The thermal interface with the SIPE shall be by conduction, convection (while inert gasses are present) and radiation. No special coatings or heaters will be required to be added to the WFC3 to cool or heat it during any part of the maintenance missions.

5.5 ELECTRICAL

5.5.1 Electrical Interfaces

The electrical and command/data systems interfaces shall be in accordance with ST-ICD-03 and ST-ICD-08. Power conditions and allotments for average, peak, and hold power shall be as described in ST-ICD-03. The RIU power budget, as given in ST-ICD-08, shall be charged to the WFC3 power allotment.

5.5.2 Electrical Design

5.5.2.1 Scope of Design

The WFC3 electrical design shall be capable of exercising the instrument in all modes as defined by this specification. It shall include all elements required to support the WFC3, including spacecraft interface, command and control, engineering and science data collection, thermal control, power configuration, electronic configuration, and redundancy.

5.5.2.2 RIU Interface

The WFC3 electrical design shall incorporate the SI C&DH Remote Interface Unit (RIU) and shall contain sufficient design margin to meet the life requirements of this specification.

5.5.2.3 Science Data

The WFC3 shall provide for the acquisition, formatting, buffering, annotation, and control of science data through the Science Data Formatter (SDF) interface as specified in ST-ICD-08. The science data shall include, as a minimum, observation data and engineering data required to annotate, calibrate, categorize, and clearly identify the telemetered science data.

5.5.2.4 Software Modifications

The WFC3 shall have the capability to receive time code updates from the spacecraft clock when commanded.

5.5.2.5 Engineering Data and Monitoring

The WFC3 instrumentation shall provide the necessary engineering data to enable monitoring and evaluation of instrument status through the RIU interface as specified in ST-ICD-08. It shall provide continuous, on-board, real-time monitoring of critical elements and the ability to switch the instrument to a safe condition, without real-time ground commands, should hazardous conditions exist. The SIPE interface shall be as defined in ST-ICD-83.

5.5.3 Electrical Redundancy

System redundancy shall be provided that is capable of controlling all WFC3 internal subsystems and of interfacing with the RIU's and the SDF. The WFC3 shall be capable of operating through either RIU and either SDF port. The electrical design shall use redundancy where practical and shall not preclude operational workarounds in the event of different failures on each of the redundant systems.

5.6 SOFTWARE

The WFC 3 flight software shall be partitioned between the NSSC-1 application processors and the WFC3 processors.

5.6.1 NSSC-1 Flight Software Interfaces

The WFC3 flight software in the NSSC-1 shall control the following operations:

5.6.1.1 Monitoring

Monitor WFC3 engineering data for unsafe conditions.

5.6.1.2 Take Data Flag Handling

Retrieve and forward the HST Take-Data-Flag.

5.6.1.3 Requests Response

Receive special engineering data from the WFC3 instrument and respond to requests embedded in this special engineering data, including: 1) posting Executive Status Buffer messages; and 2) commanding the WFC3 to a safe or suspend state.

5.6.1.4 Macro Commands

Send macro commands to the WFC3 instrument flight software.

5.6.2 WFC3 Internal Flight Software

The flight software in the WFC3 shall perform the following functions, as a minimum:

5.6.2.1 Command Handling

Receive, decode, and execute commands.

5.6.2.2 Control

Control mechanisms.

5.6.2.3 Science Data Control

Control and acquire science data from the detector.

5.6.2.4 Science Data Management

Format, buffer, and queue science data for output.

5.6.2.5 Engineering Data Management

Collect, format, and process engineering data for output to the NSSC-1.

5.6.2.6 Coordination

Control and coordinate WFC3 activities.

5.6.2.7 Engineering Monitoring

Monitor engineering data for unsafe conditions and report to the NSSC-1 need to safe or suspend.

5.6.2.8 Self Tests

Perform self tests.

5.6.2.9 Error Conditions Reporting

Collect error conditions for output to the NSSC-1.

5.6.3 Software Design

The WFC3 software design shall be capable of exercising the instrument in all modes to the performance and functional requirements as defined by this specification. It shall include all elements required to support the WFC3, including receipt, decode, and execution of commands received from the SI C&DH; control of instrument operations; collection, formatting, processing, and output of engineering and science data to the NSSC-1 and SDF, respectively; detection of instrument anomalies; maintenance of the instrument in a safe state; management of instrument memory, and self-diagnostics.

The WFC3 flight software shall be capable of being modified on-orbit.

Ground test software shall be designed for operation of the WFC3 at NASA/GSFC, through the HST ground communications system, to produce and reduce sufficient science and engineering data to optically align and functionally verify instrument operation, to evaluate performance characteristics, and to perform calibration.

5.7 OPERATIONS

5.7.1 Operations Interfaces

Operation of the WFC3 shall occur in the same manner as the Advanced Camera for Surveys (ACS). Time-tagged command blocks will be transmitted from the ground to the NSSC-1 on HST. These commands shall be structured such that observations can begin, terminate, and the data dispositioned at pre-specified times. For observations, a pre-specified amount of data at the pre-specified time shall be provided by the WFC3.

The HST will provide the following to the WFC3:

5.7.1.1 RIU discrete commands.

5.7.1.2 Observation and maintenance commands.

5.7.1.3 Spacecraft time.

5.7.1.4 Target lock indicator.

5.7.1.5 Health monitoring.

5.7.1.6 Transmission of engineering and science data to the ground.

5.7.1.7 Error handling.

5.7.2 Operations Design

The WFC3 design shall support the following operating requirements:

5.7.2.1 Response to loss of lock.

5.7.2.2 South Atlantic Anomaly safe operation.

The WFC3 shall be capable of passing through the SAA with no affect on any internal systems for at least 5 years other than not being able to obtain science data during such passages. It is acceptable to require that WFC3 transition from OBSERVE to OPERATE mode prior to SAA entry.

5.7.2.3 Transfer of science data at commandable times.

5.7.2.4 Hierarchical instrument configuration states and transitions between states.

6 PERFORMANCE ASSURANCE

6.1 FLIGHT ASSURANCE

Flight Assurance shall be performed in accordance with an approved Flight Assurance Program that encompasses all flight hardware and software per STR-43.

6.2 TEST AND VERIFICATION

6.2.1 Performance Verification Plan

Test and verification shall be accomplished per STR-43, SCM-1030, STR-29, and the approved Performance Verification Plan and shall ensure that the WFC3 hardware and software conform to the design, fabrication, and performance requirements for a protoflight unit as specified herein. Test or analysis, as defined in the approved Performance Verification Plan, shall verify each requirement.

6.2.2 Subsystem Testing

All subsystems shall be qualified prior to integration to the next highest level.

6.2.3 Life Testing

Life testing shall be performed, as required, to verify that the WFC3 will meet the life requirements specified herein. Lifetime requirements shall be derived from estimates of nominal use during ground testing and calibration, and over the course of a five-year flight mission, plus contingency, that includes science observations and calibration, as a minimum.

6.2.4 Minimum Test Suite

As a minimum, the following tests shall be performed in the completed WFC3 protoflight unit.

6.2.4.1 Functional Test

Operational tests of WFC3 shall be performed wherein all functions are checked for compliance with the applicable specifications. Functional tests shall be run periodically throughout the test program, including before and after environmental tests.

6.2.4.2 Vibration/Acoustics

Vibration/acoustics tests shall be performed at protoflight levels in accordance with GEVS-SE as reflected in STR-43.

6.2.4.3 Acceleration

Acceleration requirements will be verified by analysis and a combination of random and quasi-static load tests performed at proto-flight levels in accordance with the guidelines of GEVS-SE as reflected in STR-43.

6.2.4.4 Thermal Balance

A thermal balance test shall be performed for two cases (hot operate and cold hold) to verify the WFC3 thermal design. Transitions between conditions shall be controlled to obtain sufficient data for transient thermal math model correlation. A light stimulus shall be applied during the hot operate case to verify alignment of WFC3.

6.2.4.5 Thermal Vacuum

Functional operations and performance testing shall be conducted in thermal vacuum, as applicable, for verification and calibration per GEVS-SE as reflected in STR-43. A minimum of 2 cycles shall be used for thermal vacuum verification.

6.2.4.6 Electromagnetic Compatibility (EMC)

The WFC3 shall be designed for electromagnetic self-compatibility with HST for all phases of the mission and for EMC with the shuttle for those phases of the mission in which HST is active and in proximity with the shuttle. The WFC3 shall be designed and tested per ST-ICD-03.

6.2.4.7 Magnetics

The WFC3 shall be tested for magnetic field intensity and susceptibility to demonstrate compliance with ST-ICD-03.

6.2.4.8 Envelope

The physical envelope dimensions of the WFC3 shall be verified to demonstrate compliance with ST-ICD-03.

6.2.4.9 Mass Properties

Mass properties measurements, including center of gravity and moments of inertia of the complete end item SI, shall be performed to demonstrate compliance with ST-ICD-03.

6.3 Calibration

The WFC3 shall be operated in facilities that allow production of characteristic WFC3 images. These images shall be analyzed to determine system performance, to define operation and calibration parameters, and to verify that the performance requirements of this specification are met.

6.4 CONTAMINATION CONTROL

Contamination control shall comply with STR-29 and the approved WFC3 Contamination Control Plan. Contamination control within the WFC3 shall ensure that the instrument will meet the performance requirements specified herein over the life of the instrument.

6.5 MAINTAINABILITY

Maintainability shall be in accordance with the approved Performance Assurance Program. WFC3 components subject to maintenance shall be designed, selected, and installed to facilitate the performance of such tasks with minimum hazards to equipment and personnel and to provide for maximum use of standard tools and test equipment. The WFC3 design shall provide for easy removal and replacement, and re-alignment if necessary, of subsystems such as detectors, electronics, and major mechanisms.

6.6 CREW SYSTEMS

The WFC3 shall be designed in accordance with NSTS 07700, Vol. XIV, Appendix 7. It shall be designed to preclude damage through handling and inadvertent contact by pressure-suited crew. Shields or covers shall be provided for non-ruggedized equipment to protect against damage. The WFC 3 will be designed to meet the minimum EVA crew safety and design requirements specified in NSTS-07700, Vol. XIV, Appendix 7, and safety policy of NSTS-1700.7B.

6.7 DESIGN AND CONTRUCTION STANDARDS

The WFC3 shall be designed to minimize damage through handling and inadvertent contact by the pressure suited astronaut crew. Design and construction standards shall be in accordance with the approved WFC3 Performance Assurance Plan and STR-43. Specifications and standards necessary for the design and development of the WFC3, in addition to those specified in this document, shall be selected in the following order of preference except as otherwise specified in this document:

NASA Specifications and Standards

GSFC Specifications and Standards

Other NASA Center Specifications

Federal Specifications and Standards

Military Specifications and Standards (MIL, JAN, or MS)

Other Government Specifications

Specifications released by nationally recognized associations, committees, and technical societies

Vendor Specifications

6.7.1 Electrical

6.7.1.1 Electrical Design Standards

Electrical design standards shall be in accordance with the approved WFC3 Performance Assurance Program to ensure equivalence with NASA standards and STR-43. Electrical interfaces will be in accordance with requirements of the SI to OTA/SSM IRD STR-02D, sections 3.1.6 and 3.2.3, and the requirements of the SI to SI C&DH IRD STR-10.

6.7.1.2 Electrical, Electronic, and Electromechanical (EEE)

Parts EEE parts shall be selected in accordance with the approved WFC3 Performance Assurance Program to ensure equivalence with NASA standards and STR-43.

6.7.1.3 Electronic Component Design

All designs shall be based on conservative derating factors for components per PPL-13, Appendix B and STR-43.

6.7.1.4 Electronic Grounding

Electrical grounding shall be in accordance with ST-ICD-03. Primary DC power shall be isolated from all structure.

6.7.1.5 Redundancy

Where electronic redundancy is employed per the requirements of this specification, the WFC3 shall include the capability to verify redundant items as part of the normal ground checkout sequence. In addition, one fault shall not cause the loss of both the primary and redundant capability. Redundant critical components shall be isolated to the maximum extent possible.

6.7.2 Structural

The design shall accommodate the mechanical loads due to acceleration, thermal, vibration, and acoustic excitation as defined is ST-ICD-03. Except under emergency and crash loads, the design shall not experience plastic deformation. The structure may yield but not fracture under emergency landing. Safety factors shall be applied in accordance with GEVS-SE as reflected in STR-43.

6.7.3 Materials

The design shall use materials in accordance with STR-43. The value of thermal properties for surface finishes and insulation materials shall be verified by established references or by measurements that are submitted to GSFC for final approval per STR-43 and SCM-1030. In addition, the procedures used for fabrication and installation of thermal insulation shall be approved by GSFC. Metal parts shall be protected from corrosion by stress relieving, plating, anodizing, chemical coating, organic finish, or combinations thereof provided that such protection is compatible with the operating and environmental requirements.

6.7.4 Coordinate System

The WFC3 coordinate system shall be in accordance with ST-ICD-03.

6.7.5 Identification and Marking

Identification and marking shall be in accordance with the requirements of the approved Performance Assurance Program and Contamination Control Plan.

6.8 Radiation Properties

The radiation environment, as defined by the HST orbit and ST-ICD-03, shall be accounted for in the WFC3 design. Component selection and shielding shall be accomplished in a manner that ensures required life as well as the ability to meet the functional and performance requirements in the radiation environment.

Sensitive instrument components shall be adequately shielded from particle radiation to preclude radiation effects damage that would impair intended function for at least 5 years, and to 15 years as a design goal. No component shall be designed for early replacement (less that 5 years) due to radiation effects.

All on-board computer, memory, and control circuits shall be immune to single event upsets

6.9 MAGNETIC PROPERTIES

The WFC3 shall be capable of meeting performance requirements within the magnetic fields defined in ST-ICD-03 for other HST systems and also within the magnetic field of the defined HST orbit. Fields generated by the WFC3 shall conform to ST-ICD-03. In addition, magnetic interaction of various subsystems within the WFC3 shall not adversely affect operations or performance.

6.10 TRANSPORTABILITY

The WFC3 shall be prepared for shipment in accordance with STR-43 and shall be shipped in a container specifically designed for its protection during highway and air transportation. Vibration, shock, pressure, temperature, humidity, and contamination shall be controlled by the container to within the limits specified in ST-ICD-03 and STR-29. Provisions shall be made in the structure for suitable tie-down, lift, and attachment points. All handling and transportation equipment shall be compatible with the ST-ICD-03 structural and environmental limits. The WFC3 shall be designed to be transported in either the horizontal or vertical position.

All containers proved for the purpose of shipping WFC3 components, such as optics, shall be specifically designed to protect those components during highway and air transportation. Containers required to hermetically isolate their contents from the exterior environment shall be capable of purging with bottled gas; e.g., dry nitrogen.

Vibration, shock, pressure, temperature, and contamination shall be controlled to the limits specified in ST-ICD-03, STR-29 Contamination Control Plan.

6.11 SYSTEM SAFETY

The design shall be in compliance with the system safety requirements of STR-43.