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Integrated Design Capability / Instrument Design Laboratory

# Ocean Color Experiment Ver. 3 (OCE3) ~ *Concept Presentations* ~ Reliability

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*The IDL Team shall not distribute this material without permission  
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N A S A   G O D D A R D   S P A C E   F L I G H T   C E N T E R



# Requirements

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- **Required Mission Life**
  - 3 Years
- **Mission Goal**
  - 5 Years
- **Class C Mission**
  - From NPR 8705.4, Class C suggests a single string baseline with selective redundancy allowed for critical functions





# System Description

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## Telescope

### Scan Drum

- Rotating assembly—135 RPM
  - Between Bearing Rotor—approximately 100 mm shaft diameter
  - 1 pair of precision angular contact bearings-Basic size is 100mm
  - DC Brushless Motor
    - Redundant Windings
  - Resolver--Redundant

### Half Angle Mirror

- Rotating assembly—67.5 RPM
  - Between Bearing Rotor—approximately 12-15mm shaft diameter
  - 1 pair of precision angular contact bearings-Basic size is 12mm
  - DC Brushless Motor
    - Redundant Windings
  - Resolver--Redundant





# System Description

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## Aft Optics

### Photo Diode Array

- 1 km Array- 3 X 7 wavelengths—21 Photo Diodes
- 250 m Array-12 X 4 Wavelengths—48 Photo Diodes

### CCD's

- Non Redundant 250m (500m X 250m)
  - 6 CCDs- effectively 8 Rows by 360 Columns Each
- Redundant 1 km (2km x 1km)
  - 3 CCDs- effectively 32 Rows by 720 Columns Each

## Avionics

### Main Electronics Box 5 Cards

- 1 CPU (Single Board Computer)--Single String
- 1 Low Voltage Power Converter (LVPC)—Single String
- 1 Housekeeping and A/D Board—Single string
- 2 Heater boards- Cold Standby





# System Description

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## Avionics (Continued)

### Mechanism Control Box-9 Cards

- 2 Scan drum drive cards—Cold Standby
- 2 Momentum Compensator Drive Cards—Cold Standby
- 2 Half angle mirror mechanism Drive Cards—Cold Standby
- 2 Cradle mechanism stepper motor driver cards—Single String: 1 for each of the 2 motors driving the linkages
- 1 Sun Calibration mechanism Drive Card—Single String

### Digitizer Box—13 Cards

- 9 Digitizer Cards—Single String
- 1 Low Voltage Power Converter
- 2 CCD Cards—Single String
- 1 Readout Control Card

## Calibration Mechanism

- Stepper Motor—Single String Windings
- Resolver-Single string
- 2 Bearings





# System Description

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## Momentum Compensator

- Rotating assembly—540 RPM
  - Basic Disc Type Rotor—approximately 12-15mm shaft diameter
  - 1 pair of precision angular contact bearings
  - DC Brushless Motor
    - Redundant Windings
  - Resolver--Redundant

## Tilt Cradle

- Cradle Tilts on 2 Large “Rod End” Type Bearings—Heritage From SeaWifs
- 2 Stepper motors on linkage tilt mechanism--Heritage from SeaWifs —Single String
- 2 Sets of Back to Back Precision Angular Contact bearings on linkage between Stepper motors



# System Description

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### Thermal

- 34 Operational Heaters
  - 17 Primary Heaters
  - 10 Primary Thermostat Pairs (Fiber Optics Enclosure and Fiber Optics)
  - 7 Thermistors (PIN & Preamp Thermal Boxes)
  - 17 Redundant Heaters
  - 10 Primary Thermostat Pairs (Fiber Optics Enclosure and Fiber Optics)
  - 7 Thermistors (PIN & Preamp Thermal Boxes)
- 58 Survival Heaters (powered by the spacecraft)
  - 29 Primary
  - 29 Thermostat Pairs
  - 29 Redundant
  - 29 Thermostat Pairs

# Duty Cycles



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- **Tilt Mechanism-1% (1 minute per 98 minute orbit)**
  - Estimated at 35,000 cycles for a three year mission
  - Includes tilt bearings and linkage motors
- **Operational Heaters-70% (IDL Typical Duty Cycle)**
- **Survival Heaters-10% (IDL Typical Duty Cycle)**
- **Calibration Mechanism-Less than 1%**
- **All others are considered to be 100%**



# Assumptions

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- **Bearing loads on rotating assemblies are loaded to their recommended preloads per manufacturers recommendations.**
- **On orbit rotating radial loads in addition to the preloads are negligible and do not exceed preloads.**
  - These are very small loads with respect to a typical dynamic load rating on a bearing
  - Suggests extremely long lifetimes at the low speeds the design is calling for
- **Launch loads on the bearings do not exceed their static load ratings to create initial damage.**
- **Lubrication to the bearings is adequate, and are maintained in clean room conditions (from SKF) during integration**
- **CCD Column failures occur randomly and will not be concentrated in one given area**
  - Multiple adjacent columns failing is more severe degradation than columns failing in multiple isolated areas on the CCD

# Instrument Reliability Summary

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## OCE3

Mission Duration (years)	
Requirement:	3
Goal:	5
Extended Lifetime:	5

Master Duty Cycle:	100%
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	Mission Duration (years)					
	Selective Redundancy Design			Single String Design		
	3		5	3		5
Tilt Cradle	0.999849		0.999677	0.999849		0.999677
Avionics	0.881381		0.81011	0.865646		0.786261
Thermal	0.995265		0.987277	0.980891		0.968355
Telescope	0.960177		0.79529	0.956164		0.78977
Momentum Comp	0.980995		0.893479	0.980995		0.893479
<b>Design Reliability</b>	<b>0.83</b>		<b>0.57</b>	<b>0.80</b>		<b>0.54</b>



# Conclusions

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- Selective redundancy design does not appear to necessarily provide a large step change in reliability over single string configuration.
- At +/- 25% variations (75% to 125%) in master duty cycle (from the IDL tool) it appears that there is not a large enough statistical difference in the two designs' relative reliabilities to overwhelmingly recommend the selective redundancy approach.
- Selection will ultimately be a cost trade and should be looked at in detail.



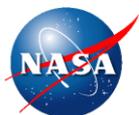


# Future Recommendations/Next Steps

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- Conduct trades to determine other reasons why selective redundancy would be necessary beyond the reliability block diagram analysis conducted here. There could be other compelling reasons for it, but are outside the scope of this week's study.
- Bearings should be selected such that launch loads on bearings do not exceed static load rating (Brinelling Threshold) with adequate margin.



# Backup Charts



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### Tilt Cradle

Subsystem / Component Name	Qty	Model	MTTF/ Char Life / Lognormal Mean	Failure Rate / Shape / Lognormal Std Dev	Relative Duty Cycle	Component Reliability (for time in years)			Redundancy Configuration	Subsystem Reliability (for time in years)		
						3	5	5		3	5	5
<b>Cradle Bearings</b>												
Cradle Bearing Spherical (From Mechanical)	1	W	2.00E+06	2.5	2%	0.999999999	0.999999997	0.999999997	Single String	0.999999998	0.999999994	0.999999994
<b>Gearmotors</b>												
Motor Winding	1	E	5000000	0.0000002	1%	0.999946367	0.999910604	0.999910604	Single String	0.999892736	0.999821217	0.999821217
Motor Bearings	2	W	100000	3.5		0.999999998	0.999999998	0.999999998				
<b>Linkage Bearings</b>												
Bearing From SKF Calculator	1	W	1000000	2.5	1%	0.999999999	0.999999996	0.999999996	Single String	0.999999998	0.999999992	0.999999992
<b>Resolver</b>												
Resolver	1	E	76923076	1.3E-08	1%	0.999996514	0.99999419	0.99999419	Single String	0.999993028	0.99998838	0.99998838
<b>Geared stepper motors</b>												
Stepper motor	1	W	21000	2.5	1%	0.999981573	0.999933922	0.999933922	Single String	0.999963147	0.999867848	0.999867848

Tilt Cradle Total			
	3 years	5 years	5 years
Min Redundancy	0.999848912	0.999677457	0.999677457
Max Redundancy	0.999848912	0.999677457	0.999677457





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### Avionics

Subsystem / Component Name	Qty	Model	MTTF/ Char Life / Lognormal Mean	Failure Rate / Shape / Lognormal Std Dev	Relative Duty Cycle	Component Reliability (for time in years)			Redundancy Configuration	Subsystem Reliability (for time in years)		
						3	5	5		3	5	5
<b>Mechanism Control Box Redundant Cards</b>	1				100%	0.983926011	0.973353817	0.973353817	Cold Standby	0.999870116	0.999641795	0.999641795
Avionics Board - Medium Complexity	3	E	4865292.2	2.05538E-07		0.983926011	0.973353817	0.973353817	Single String	0.983926011	0.973353817	0.973353817
<b>Mechanism Control Box Sun Calibration Card</b>	1				100%	0.994613036	0.991037859	0.991037859	Single String	0.994613036	0.991037859	0.991037859
Avionics Board - Medium Complexity	1	E	4865292.2	2.05538E-07		0.994613036	0.991037859	0.991037859	Single String	0.994613036	0.991037859	0.991037859
<b>MEB</b>	1				100%	0.964767882	0.941972148	0.941972148	Single String	0.964767882	0.941972148	0.941972148
Master Interface Electronic Processor (MIEP) (CPU)	1	E	1238242.092	8.07597E-07		0.979	0.965245576	0.965245576	Single String	0.964767882	0.941972148	0.941972148
power controller 2 (PC)--LVPC	1	E	2843361.498	3.51696E-07		0.9908	0.984713737	0.984713737				
Avionics Board - Medium Complexity--HK & A/D	1	E	4865292.2	2.05538E-07		0.994613036	0.991037859	0.991037859				
<b>Digitizer Boxes</b>	1				100%	0.928615151	0.883879257	0.883879257	Single String	0.928615151	0.883879257	0.883879257
Avionics Board - Medium Complexity--Digitizer card	9	E	4865292.2	2.05538E-07		0.952549	0.922172589	0.922172589	Single String	0.928615151	0.883879257	0.883879257
Avionics Board - Medium Complexity--Readout Control Card	1	E	4865292.2	2.05538E-07		0.994613036	0.991037859	0.991037859				
Avionics Board - Medium Complexity--CCD Card	2	E	4865292.2	2.05538E-07		0.989255092	0.982156038	0.982156038				
power controller 2 (PC)--LVPC	1	E	2843361.498	3.51696E-07		0.9908	0.984713737	0.984713737				
<b>Redundant Heater Board</b>	1				100%	0.99806	0.996768758	0.996768758	Cold Standby	0.999998117	0.999994774	0.999994774
heat drive electronics	1	E	13533247.5	7.38921E-08		0.99806	0.996768758	0.996768758	Single String	0.99806	0.996768758	0.996768758
<b>Mechanism Control Box Tilt Mechanism Motors</b>	2				100%	0.994613036	0.991037859	0.991037859	Single String	0.989255092	0.982156038	0.982156038
Avionics Board - Medium Complexity	1	E	4865292.2	2.05538E-07		0.994613036	0.991037859	0.991037859	Single String	0.989255092	0.982156038	0.982156038

Avionics Total			
	3 years	5 years	5 years
Min Redundancy	0.881381264	0.810109781	0.810109781
Max Redundancy	0.86564562	0.786261288	0.786261288



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### Telescope

Subsystem / Component Name	Qty	Model	MTTF/ Char Life / Lognormal Mean	Failure Rate / Shape / Lognormal Std Dev	Relative Duty Cycle	Component Reliability (for time in years)			Redundancy Configuration	Subsystem Reliability (for time in years)		
						3	5	5		3	5	5
<b>Drum Bearings</b>	1				100%	0.999776104	0.999197323	0.999197323	Single String	0.999776104	0.999197323	0.999197323
Drum Bearings SKF 7020 FB/P7 for the given dimensions (4")	2	W	1000000	2.5		0.999776104	0.999197323	0.999197323	Single String	0.999776104	0.999197323	0.999197323
<b>Half angle mirror bearings</b>	1				100%	0.999776104	0.999197323	0.999197323	Single String	0.999776104	0.999197323	0.999197323
Half angle mirror bearings (Baseline SKF 7201 BP-1/2" bore)	2	W	1000000	2.5		0.999776104	0.999197323	0.999197323	Single String	0.999776104	0.999197323	0.999197323
<b>Photodiode Array 12 X 3</b>	1				100%	0.999850214	0.999750371	0.999750371	K of N (Hot)	35 of 36	0.999850214	0.999750371
Photodiode Array	1	E	175438596.5	5.7E-09		0.999850214	0.999750371	0.999750371	Single String	0.999850214	0.999750371	0.999750371
<b>Photodiode Array 3X5</b>	1				100%	0.999850214	0.999750371	0.999750371	K of N (Hot)	15 of 15	0.999850214	0.999750371
Photodiode Array	1	E	175438596.5	5.7E-09		0.999850214	0.999750371	0.999750371	Single String	0.999850214	0.999750371	0.999750371
<b>CCD 1 km</b>	1				100%	0.999316953	0.998861848	0.998861848	K of N (Hot)	700 of 720	0.999316953	0.998861848
CCD (Used Star Tracker Head failure rate)	1	E	38461538.46	0.000000028		0.999316953	0.998861848	0.998861848	Single String	0.999316953	0.998861848	0.998861848
<b>CCD 2 1 km</b>	1				100%	0.999316953	0.998861848	0.998861848	K of N (Hot)	700 of 720	0.999316953	0.998861848
CCD (Used Star Tracker Head failure rate)	1	E	38461538.46	0.000000028		0.999316953	0.998861848	0.998861848	Single String	0.999316953	0.998861848	0.998861848
<b>CCD 3 1km</b>	1				100%	0.999316953	0.998861848	0.998861848	K of N (Hot)	700 of 720	0.999316953	0.998861848
CCD (Used Star Tracker Head failure rate)	1	E	38461538.46	0.000000028		0.999316953	0.998861848	0.998861848	Single String	0.999316953	0.998861848	0.998861848
<b>CCD Non redundant 250m</b>	6				100%	0.999316953	0.998861848	0.998861848	K of N (Hot)	350 of 360	0.999316953	0.998861848
Star Tracker Head (Mini Star Tracker)	1	E	38461538.46	0.000000028		0.999316953	0.998861848	0.998861848	Single String	0.999316953	0.998861848	0.998861848
<b>Drive Motor and Resolver includes Both Drum and Half angle Mirror</b>	2				100%	0.98154969	0.894706121	0.894706121	Single String	0.963439795	0.800499043	0.800499043
Motor Winding Redundant	1	U				0.999986236	0.999961855	0.999961855	Single String	0.963439795	0.800499043	0.800499043
Motor Bearings	2	W	100000	3.5		0.981563258	0.894740397	0.894740397				
Redundant Resolver	1	U				0.999999942	0.999999938	0.999999938				

Telescope Total			
	3 years	5 years	5 years
<b>Min Redundancy</b>	0.960833496	0.796196011	0.796196011
<b>Max Redundancy</b>	0.956817854	0.790670104	0.790670104

<b>Redundant Motor Winding</b>	1				100%	0.994757783	0.991278257	0.991278257	Cold Standby	0.999986236	0.999961855	0.999961855
Motor Winding	1	E	5000000	0.000000028		0.994757783	0.991278257	0.991278257	Single String	0.994757783	0.991278257	0.991278257
<b>Redundant Resolver</b>	1				100%	0.999658414	0.999430763	0.999430763	Cold Standby	0.999999942	0.999999938	0.999999938
Resolver	1	E	76923076	1.3E-08		0.999658414	0.999430763	0.999430763	Single String	0.999658414	0.999430763	0.999430763





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### Thermal

Subsystem / Component Name	Qty	Model	MTTF/ Char Life / Lognormal Mean	Failure Rate / Shape / Lognormal Std Dev	Relative Duty Cycle	Component Reliability (for time in years)			Redundancy Configuration	Subsystem Reliability (for time in years)		
						3	5	5		3	5	5
									30	of	34	
<b>Operational Heaters</b>	1				70%	0.992444171	0.987438696	0.987438696	K of N (Hot)	0.999994292	0.999935781	0.999935781
Heater	1	E	2530883.726	3.95119E-07		0.992757745	0.987958738	0.987958738	Single String	0.992444171	0.987438696	0.987438696
thermistor	1	E	460232043.8	2.17282E-09		0.99996003	0.999933384	0.999933384				
Thermostat Pair	1	E	66666666.67	0.00000015		0.999724098	0.999540206	0.999540206				
									45	of	50	
<b>Survival Heaters</b>	1				10%	0.998909975	0.998183951	0.998183951	K of N (Hot)	0.999999999	0.999999999	0.999999999
Heater	1	E	2500000	0.0000004		0.998949352	0.998249534	0.998249534	Single String	0.998909975	0.998183951	0.998183951
Thermostat Pair	1	E	66666666.67	0.00000015		0.999960581	0.999934302	0.999934302				
<b>CCHPs</b>	6				100%	0.99957	0.999283436	0.999283436	Hot Redundancy	0.999998891	0.999996919	0.999996919
fixed conductance heat pipe (FCHP)	1	E	61103138.13	1.63658E-08		0.99957	0.999283436	0.999283436	Single String	0.997422772	0.995708311	0.995708311

Thermal Total			
	3 years	5 years	5 years
Min Redundancy	0.999993182	0.9999327	0.9999327
Max Redundancy	0.986807415	0.981415375	0.981415375





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### Momentum Comp

Subsystem / Component Name	Qty	Model	MTTF/ Char Life / Lognormal Mean	Failure Rate / Shape / Lognormal Std Dev	Relative Duty Cycle	Component Reliability (for time in years)			Redundancy Configuration	Subsystem Reliability (for time in years)		
						3	5	5		3	5	5
<b>Motor and Resolver</b>	1				100%	0.98154969	0.894706121	0.894706121	Single String	0.98154969	0.894706121	0.894706121
Redundant Motor Winding	1	U				0.999986236	0.999961855	0.999961855	Single String	0.98154969	0.894706121	0.894706121
Motor Bearings	2	W	100000	3.5		0.981563258	0.894740397	0.894740397				
Redundant Resolver	1	U				0.999999942	0.999999838	0.999999838				
<b>Momentum compensator Bearings</b>	2				100%	0.999888046	0.999598581	0.999598581	Single String	0.999776105	0.999197323	0.999197323
Momentum compensator Bearings	1	W	1000000	2.5		0.999888046	0.999598581	0.999598581	Single String	0.999776105	0.999197323	0.999197323

### Momentum Comp Total

	3 years	5 years	5 years
Min Redundancy	0.981329926	0.893987961	0.893987961
Max Redundancy	0.981329926	0.893987961	0.893987961

<b>Redundant Motor Winding</b>	1				100%	0.994757789	0.991278257	0.991278257	Cold Standby	0.999986236	0.999961855	0.999961855
Motor Winding	1	E	5000000	0.0000002		0.994757789	0.991278257	0.991278257	Single String	0.994757789	0.991278257	0.991278257
			70956000									
			354780000	5yr								
			212868000	3 yr								
											1419120000	
<b>Redundant Resolver</b>	1				100%	0.999658418	0.999430762	0.999430762	Cold Standby	0.999999942	0.999999838	0.999999838
Resolver	1	E	76923076	1.3E-08		0.999658418	0.999430762	0.999430762	Single String	0.999658418	0.999430762	0.999430762



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# OCE3

Mission Duration (years)	
Requirement:	3
Goal:	5
Extended Lifetime:	5

False

Master Duty Cycle:	100%
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	Mission Duration (years)						
	Selective Redundancy				Single String		
	3	5	5		3	5	5
Tilt Cradle	0.999849	0.999677	0.999677		0.999849	0.999677	0.999677
Avionics	0.881381	0.81011	0.81011		0.865646	0.786261	0.786261
Telescope	0.960833	0.796196	0.796196		0.956818	0.79067	0.79067
Thermal	0.999993	0.999933	0.999933		0.988807	0.981415	0.981415
Momentum Comp	0.98133	0.893988	0.893988		0.98133	0.893988	0.893988
Design Reliability	0.830918	0.576403	0.576403		0.803583	0.545264	0.545264