GEMMA
Gemini North Adaptive Optics and Real Time Computer
Project Execution Plan Review

David Palmer, Henry Roe, Gaetano Sivo, Julia Scharwächter, Stephen Goodsell, Natalie Provost, and the GNAO/RTC Team

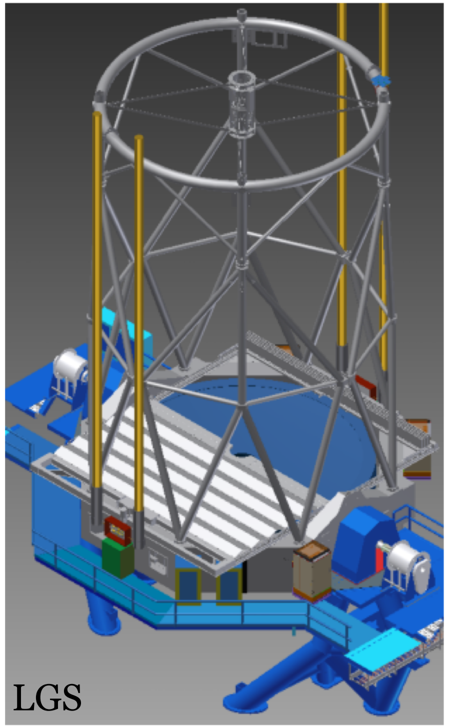
NSF Headquarters – July 10th, 2019

Topics

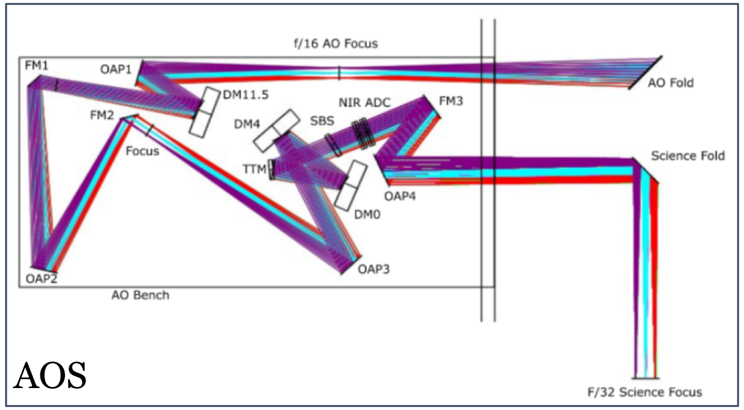
- Introduction.
- Brief technical description for context.
- In-depth project plan.
- Risks.
- Systems Engineering plan.
- Summary.

2 Projects Into 1 – GNAO/RTC

- Until early May, 2019, the GEMMA Program contained 2 separate projects: the Gemini North Adaptive Optics (GNAO) project and the Real-Time Computer (RTC) project.
- Due to considerable synergies between the GNAO and RTC projects and to improve management and execution efficiencies, Gemini has merged these two projects.
- The RTC will be a subsystem of GNAO.

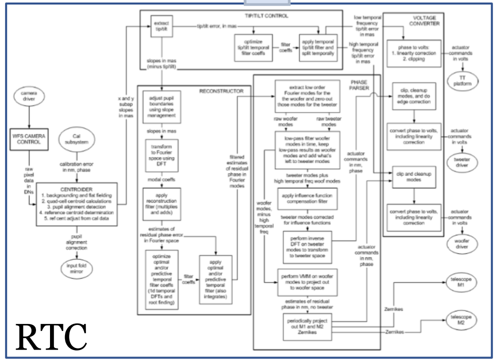


LGS



AOS

GNAO to GNAO/RTC



RTC

High-level GNAO/RTC Accomplishments To Date

1.1 Meetings and Milestones

- Scheduled firm dates for the CoDR and tentative dates for the remaining main project reviews.
- Set milestones on a per subsystem basis.

1.2 Project Management, including non-subsystem-specific SE

- Identified and added the staff needed to manage and perform the GNAO/RTC project.
- Constructed a credible, fully-resourced project plan.
- Raised the project to very high priority in the observatory.
- Organized the project team for efficient performance.
- Performed functional decomposition and flowed down requirements.
- Advanced inter-subsystem and external interface definition.

1.3 Science, including the AOWG

- Assembled a science team and Adaptive Optics (AO) working group, both involving many external participants.
- Identified and fleshed out science cases pertinent to GNAO/RTC.
- Derived near-final science requirements from the science cases.
- Progressed the Concept of Operations (ConOps) document.
- Performed detailed AO simulations to estimate performance and inform design choices.

High-level GNAO/RTC Accomplishments To Date, cont.

1.4 Laser Guide Star Subsystem (LGS)

- Considered several laser configurations, weighing performance and cost.
- Advanced several optical design concepts, leading to a near-final conceptual optical design.
- Advanced several mechanic design concepts, leading to a near-final conceptual mechanical design.
- Considered electrical needs, including re-use of existing electronics and systems.
- Preliminarily selected and costed hardware for the LGS.

1.5 Adaptive Optics Subsystem (AOS)

- Prepared a near-final conceptual optical design.
- Advanced a conceptual mechanical design.
- Preliminarily selected and costed hardware for the AOS, including WFS cameras, DMs, and TT.
- Functionally decomposed computers and software for the subsystems and the Top Level Computer (TLC).

1.6 Real-Time Computer (RTC)

- Calculated required computing power and did a preliminary computer selection.
- Identified and began evaluating candidate RTC packages.

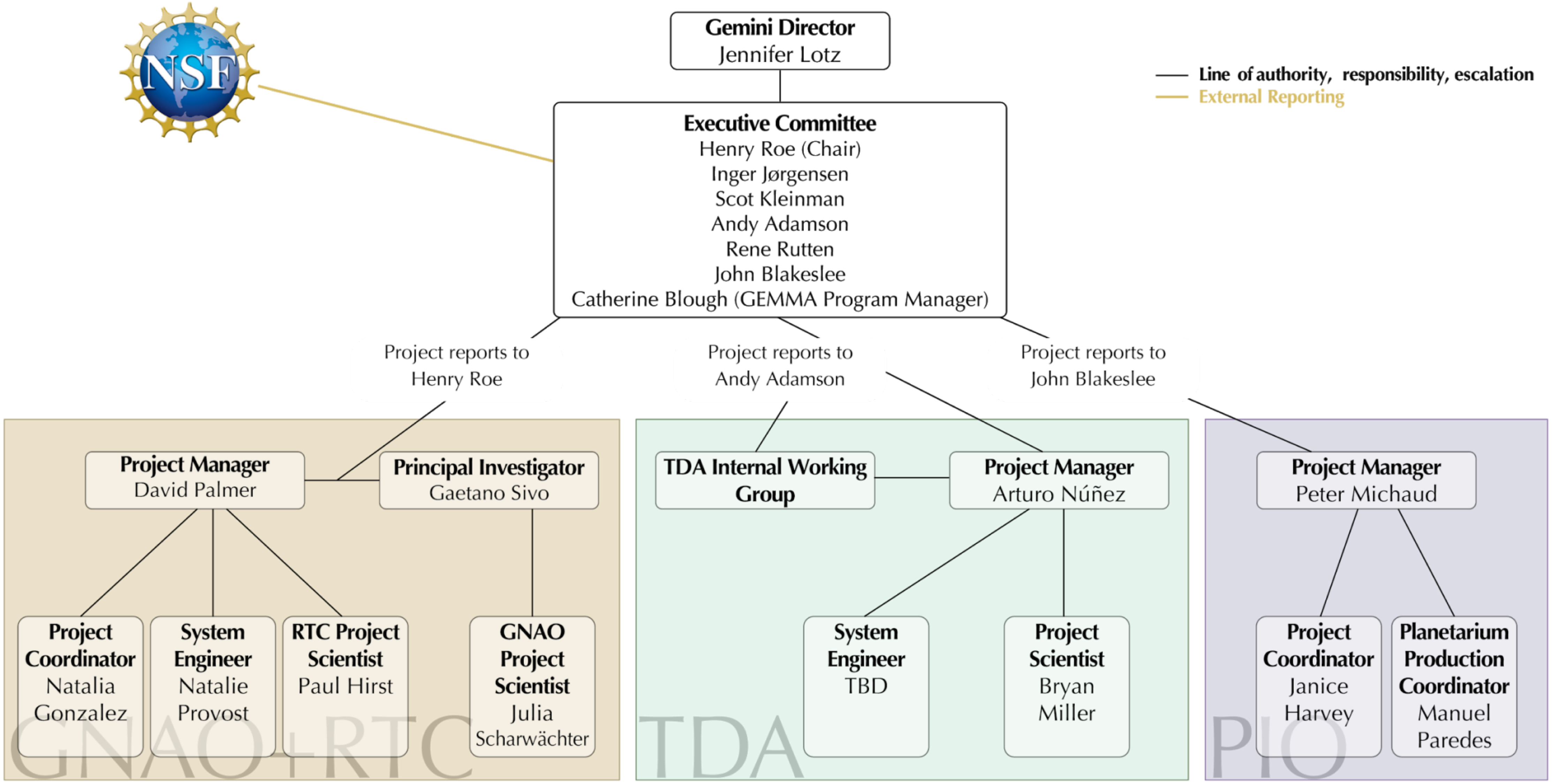
Nearly-Final GNAO/RTC Science Requirements

REQ-ID	Metric	Requirement	Primary Science Driver
	GNAO Top Level Science		
GNAO-001	Corrected Field of View	2' circular diameter	JWST Synergy (2.2')
GNAO-002	Strehl ratio	no less than 30% over the entire FoV under good conditions no less than 50% over the entire FoV under excellent conditions, at 2.2 microns	Galactic and extragalactic clusters
GNAO-003	Astrometry accuracy with 3 NGSs under median seeing conditions	0.2 mas	Galactic and extragalactic clusters, Galactic Nucleus, astrometric exoplanets and internal kinematics of dense, resolved stellar systems
GNAO-004	Seeing Limit for Closed loop Operations	up to 1.2" @ 0.5 μm	Rapid Target of Opportunity (seeing in bad conditions)
GNAO-005	Sky coverage with 1 NGS	60% at galactic pole	Ability to reach extragalactic deep fields
GNAO-006	Sky coverage with 3 NGSs	20% at galactic pole	Reach deep galactic fields, Supernovae
GNAO-007	Wavelength Coverage	GNAO shall deliver a science corrected beam between 850nm < λ < 2.5μm	The majority of the driving science cases need standard JHK coverage.
GNAO-008	Photometric Accuracy	Accuracy better than 0.5%	Needed for measuring magnitudes of stars in dense field
GNAO-009	Focal Ratio	F/32	Optimized use with existing instruments Synergy of GLAO and MCAO
GNAO-010	Temporal performance / PSF Stability	The shape of the GNAO PSF should remain constant within 10% under the best observing conditions over (realistic) elevation variations	Galactic young massive star clusters
GNAO-011	Spatial performance / PSF Quality	The shape of the GNAO PSF should remain constant within 10% under the best observing conditions over (realistic) elevation variations (e.g. 0 degrees from Zenith to 45 degrees)	Galactic science (crowded regions)
GNAO-012	PSF Spatial stability (within the FOV)	PSF shall vary less than TBD% over the field of view.	
GNAO-013	Static Field Distortion (Less than x% from center to edge)	The static field distortion shall be less than 2% from the center to the edge of the field of view. (TBR)	Astrometry and weak lensing
GNAO-014	Dynamic Field Distortion	0.2 mas across the field (changes over time)	Astrometry. 0.2 mas corresponds to xx distance of galactic center
GNAO-015	Chromatic effects	No chromatic effects detectable at a R = 10,000	Spectroscopy
GNAO-017	Exposure time	10 minutes	Spectroscopy
GNAO-019	GLAO Compatibility	Must not preclude	
GNAO-020	Throughput	75% over the required wavelength range	All
GNAO-021	Emissivity	For wavelength of 2.2 microns, emmisivity shall be <19%	
GNAO-024	Zenith Angle	meet performance up to 45 degree zenith angle, operational up to 60 degree zenith angle	Galactic center

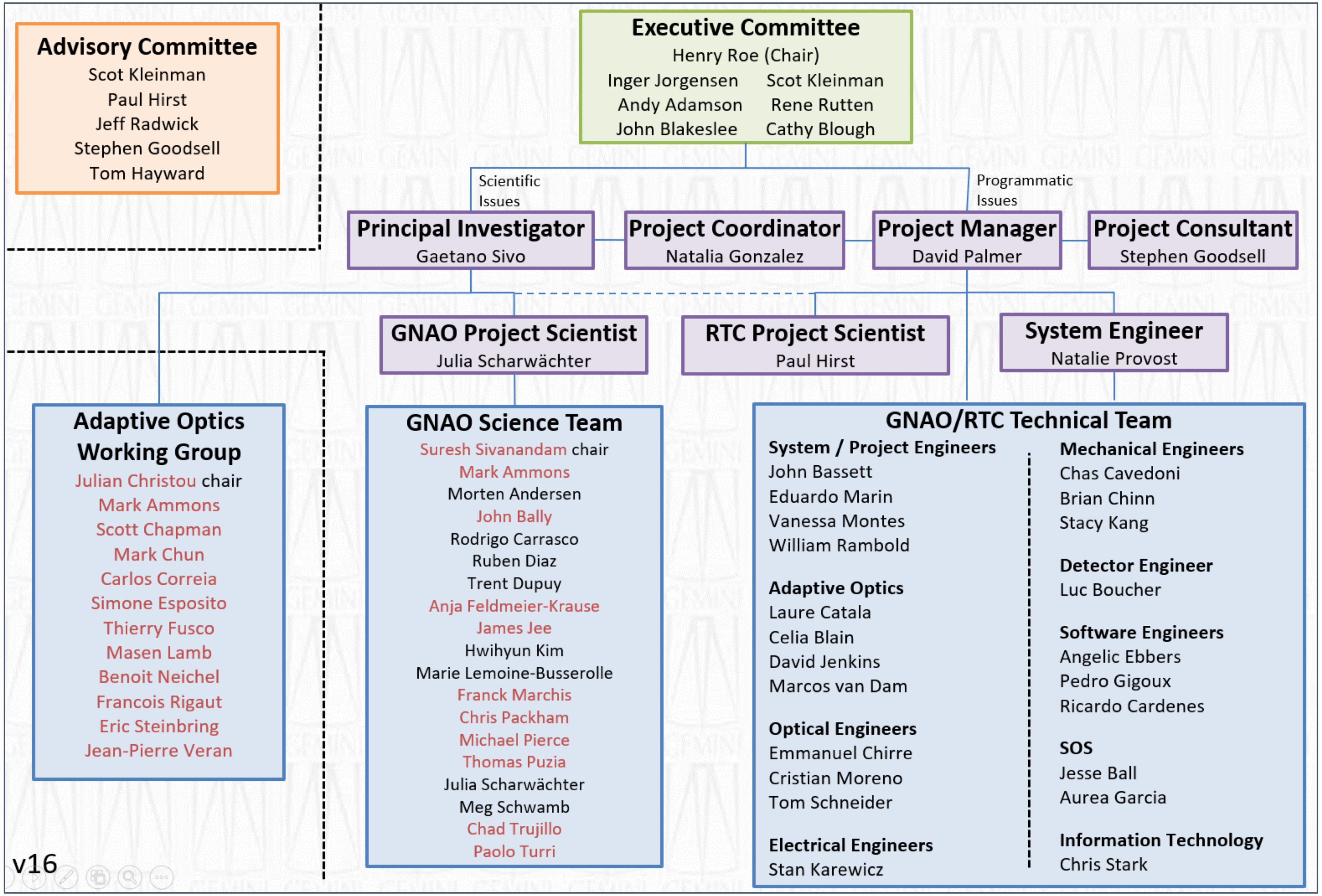
Gemini's ICDs and Specification Documents That GNAO/RTC Will Comply With

General Gemini Facility ICDs
• Gemini Observatory Facility Instrument Common Requirements and Standards Specification (version C)
• ICD 1.9/5.0 Science and Facility Instruments to Transport, Observatory and Operations Environments ICD (version C) – This includes environmental temperature ranges, etc.
• ICD 1.5.3/1.9 ISS to Science Instruments ICD (version D)
• ICD 1.9/3.6 Science and Facility Instruments to ISS System Services ICD (version F)
• ICD 1.9/2.7 Science Instruments to Facility Handling Equipment ICD (version E)
• ICD-G0014 Optomechanical Coordinate System (version B)
General Gemini Software Requirements, Standards, and ICDs
• GIAPI Builder Req-01302009 GIAPI Software Requirements for Instrument Builders (version 04) ICD 50
• GIAPI C++ Language Glue API ICD (version 11)
• GIAPI Use-08292006 GIAPI Design and Use (version 08)
• GPSG-STD-102 Coding Standards and Guidelines for the Gemini Data Processing Software (in development)
• Gemini Recipe System documentation (in development)
Applicable Software ICDs
• 1.1.13/1.9 Interlock System to Science Instruments ICD (version A)
• ICD 10 EPICS Synchro Bus Driver (version 13 - Nov 1997)
• ICD 20 Synchro Bus - Node/Page Specifications (version D)
Applicable Telescope Subsystem ICDs
• Telescope Control System (TCS) ICD
• Secondary Control System (SCS) ICD
• Acquisition and Guidance System (A&G) ICD
• Observatory Control System (OCS) ICD
• Data Handling System (DHS) ICD
• Gemini Interlock System (GIS) ICD

GEMMA Organizational Structure



GNAO/RTC Project Organizational Structure



red indicates external participants

GNAO/RTC Technical Organizational Structure

Principal Investigator
Gaetano Sivo

Project Manager
David Palmer

Systems Engineer
Natalie Provost

LGS Subsystem Lead
Eduardo Marin

AOS Subsystem Lead
Gaetano Sivo

TLC Lead
David Palmer

RTC Subsystem Lead
Paul Hirst

LGS Subsystem Team

Subsys Eng: John Bassett

Opt Eng: Tom Schneider

Mech Eng: Chas Cavedoni
Mech Designer: Stacy Kang

Elect Eng: Stan Karewicz

SW Eng: Angelic Ebbers

SOS: Jesse Ball

AOS Subsystem Team

Subcont Mgr: Celia Blain

Subsys Eng: Natalie Provost

AO Scientist: Laure Catala
AO Scientist: Marcos van Dam

Opt Eng: Emmanuel Chirre
Opt Eng: Cristian Moreno

Mech Eng: Brian Chinn

SW Eng: Pedro Gigoux

SOS: Aurea Garcia

TLC Team

Subsys Eng: William Rambold

SW Eng: Angelic Ebbers
SW Eng: Pedro Gigoux
SW Eng: Ricardo Cardenes

RTC Subsystem Team

Subsys Eng: William Rambold

HW/SW Eng: Paul Hirst
HW/SW Eng: David Palmer

SW Eng: William Rambold
SW Eng: David Jenkins

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Technical Org Structure, cont., plus meetings

The purpose for the more detailed technical org chart given on the previous slide is to better focus the work to be performed and the corresponding communication. This standard project organization empowers the subsystem leads to perform their jobs, along with their teams, reporting progress and problems up to the PM. The following meetings have been or are being stood up to facilitate communication:

Description	Organizer	Frequency	Day / time	Length	Attendees
Team-Lead meetings	Dave / Natalia	weekly	Mon at 9:00 AM HST	hour	Dave, Gaetano, Julia, Natalie, Eduardo, Paul, Natalia
Team-Lead catchup	Dave / Natalia	weekly	Thurs at 10:30 AM HST	1/2 hour	Dave, Gaetano, Julia, Natalie, Eduardo, Paul, Natalia
Team meetings	Dave / Natalia	monthly	Tues at 9:00 AM HST, first or last Tues of month	hour	all
System Working Group	Natalie	weekly	Wed at 9:00 AM HST	hour	as required
LGS team	Eduardo	weekly	Tues at 11:00 AM HST	1/2 hour	LGS team
AOS team	Gaetano	weekly	Thurs at 11:00 AM HST	hour	AOS team
TLC team	Dave	weekly	Fri at 10:00 AM HST	hour	TLC team
RTC team	Paul	weekly		hour	RTC team
AOWG	Gaetano	every-other-week	variable	hour	AOWG
Science	Morten / Julia	weekly	Tues at 11:30 AM HST	1/2 hour	science team
ConOps	Julia	as required	as required	variable	ConOps team
virtual hallway	Dave / Natalia	twice per week	Tues and Thurs at 8:30 AM HST	1/2 hour	optional, anyone

Topics

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- **Brief technical description for context.**
- In-depth project plan.
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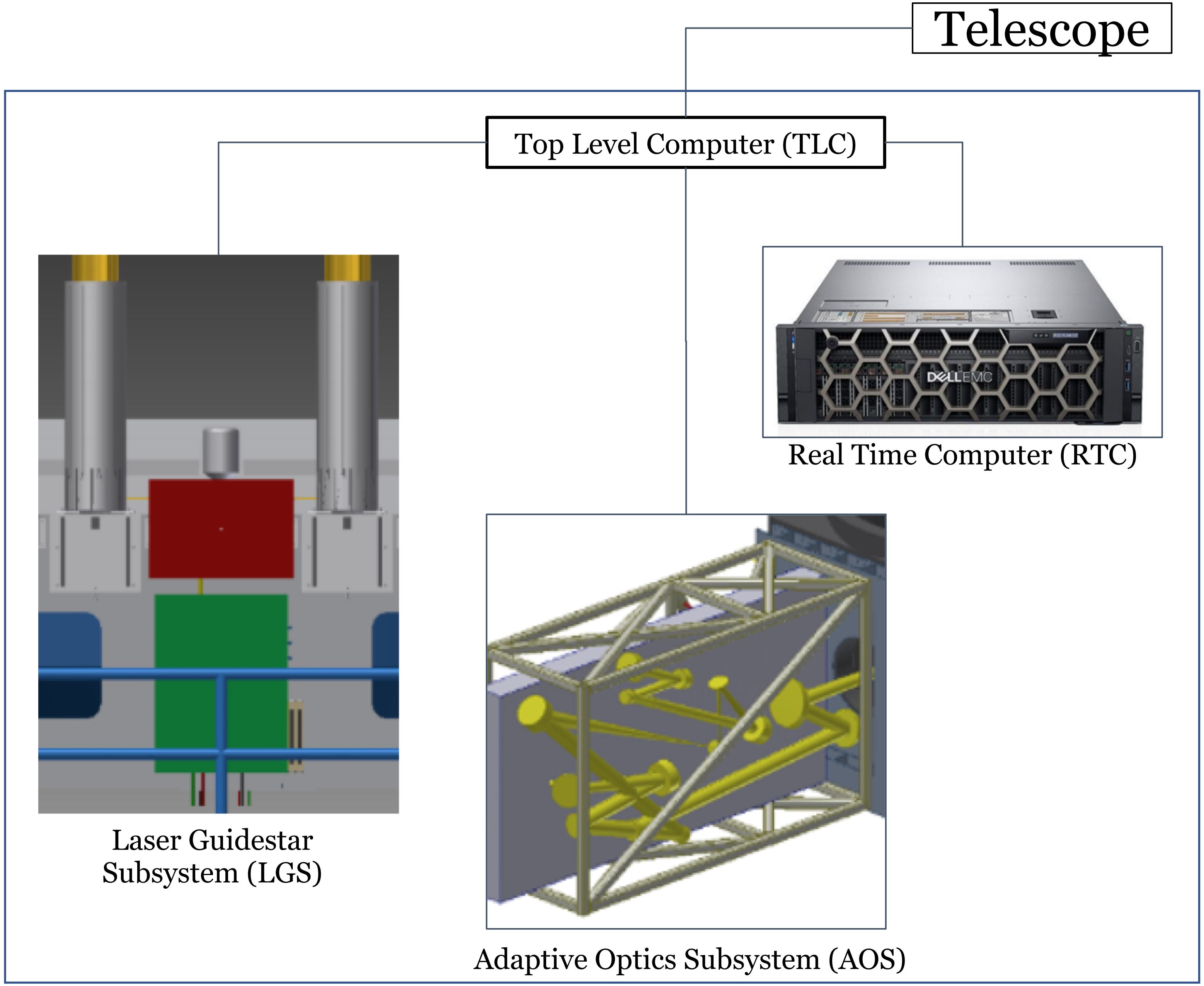
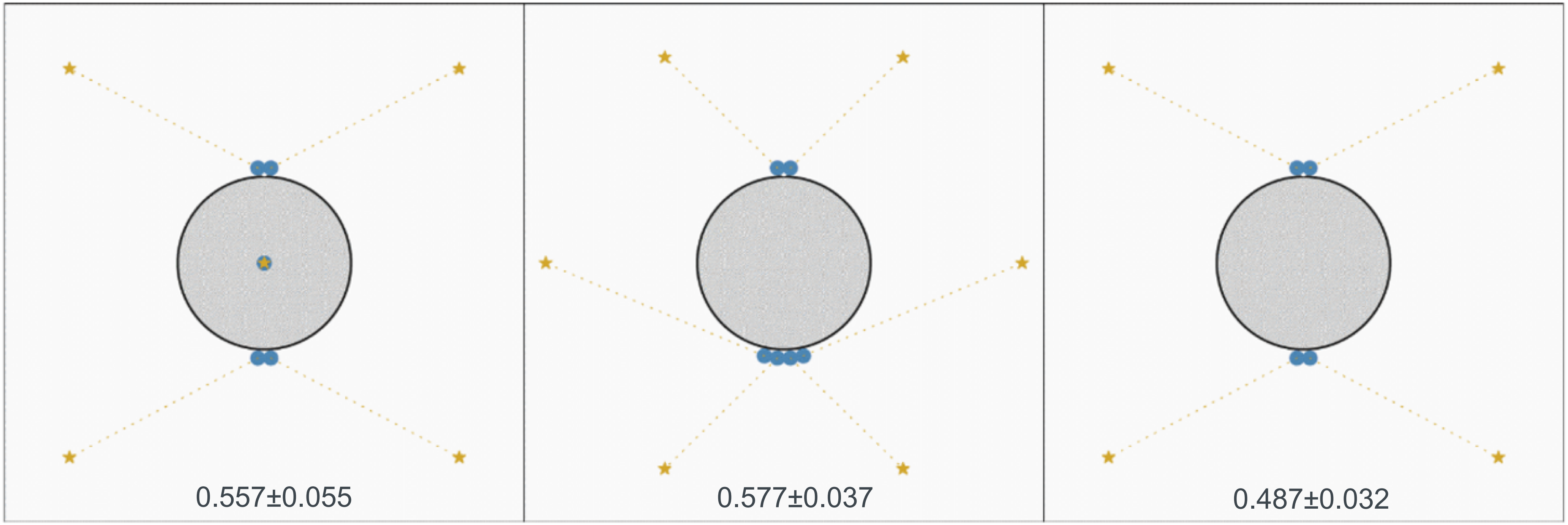
GNAO/RTC Subsystems Overview



The Laser Guide-Star Subsystem (LGS)

- The LGS uses lasers to cause sodium in the upper atmosphere to fluoresce and, thereby, forms ‘stars’ that the AO subsystem (AOS) can use to correct atmospheric turbulence (instead of natural guide-stars that are only sparsely available with adequate brightness).
- We are considering several configurations, weighing cost and performance (we already have 1 laser and a center Laser Launch Telescope (LLT)):
  - 3/5/5 (left): 5 spots using 3 lasers, 4 new LLTs, and the existing center LLT.
  - 3/6/6 (center): 6 spots using 3 lasers and 6 new LLTs.
  - 2/4/4 (right): 4 spots using 2 lasers and 4 new LLTs.



The numbers given are K-band Strehl ratios (average and standard deviation across the field), median seeing, from simulations (v1.1:2 July 2019, tables 7-9).

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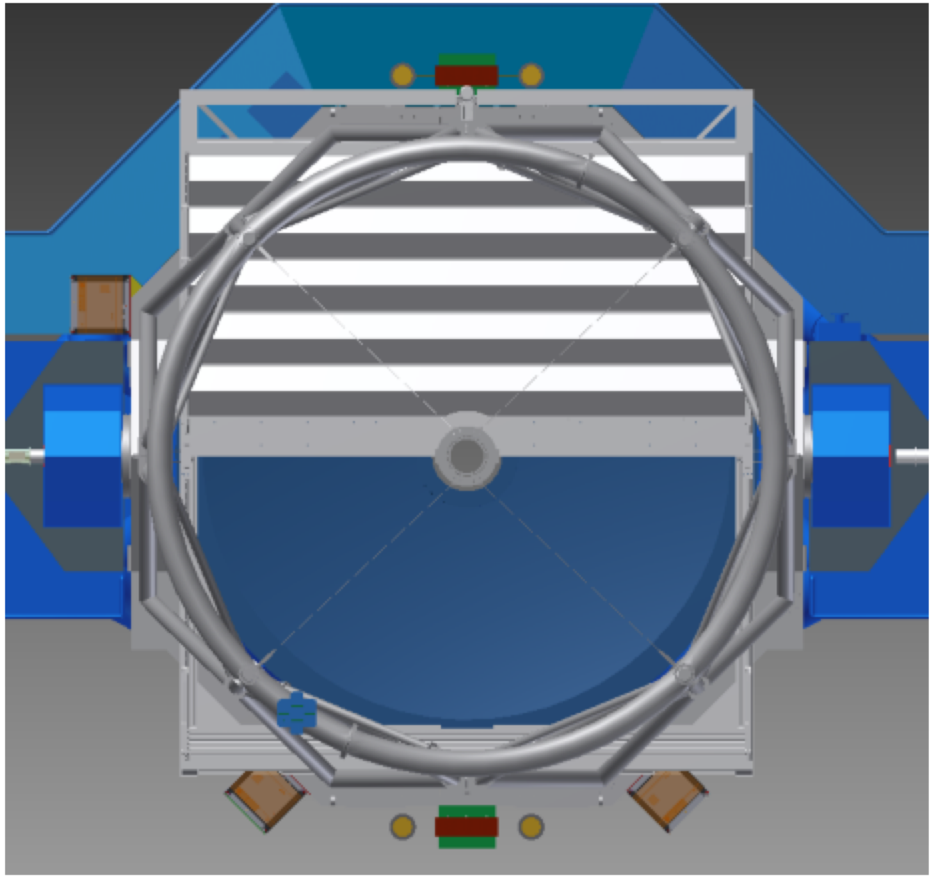
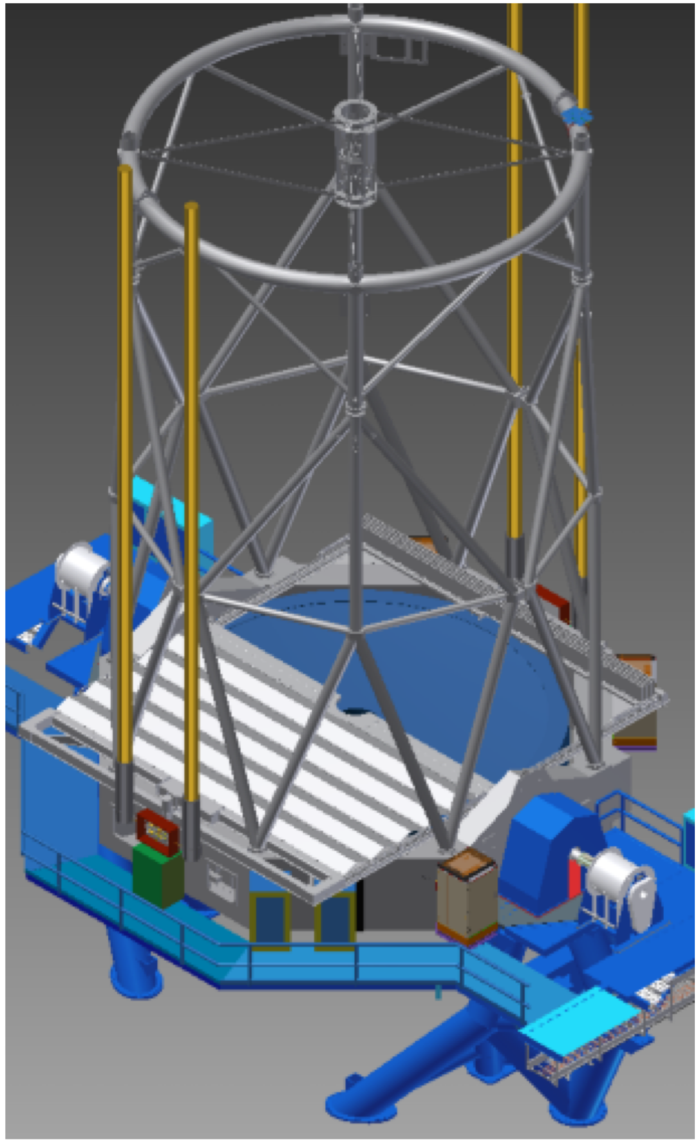
Conceptual top and side views of the 2/4/4 LGS option





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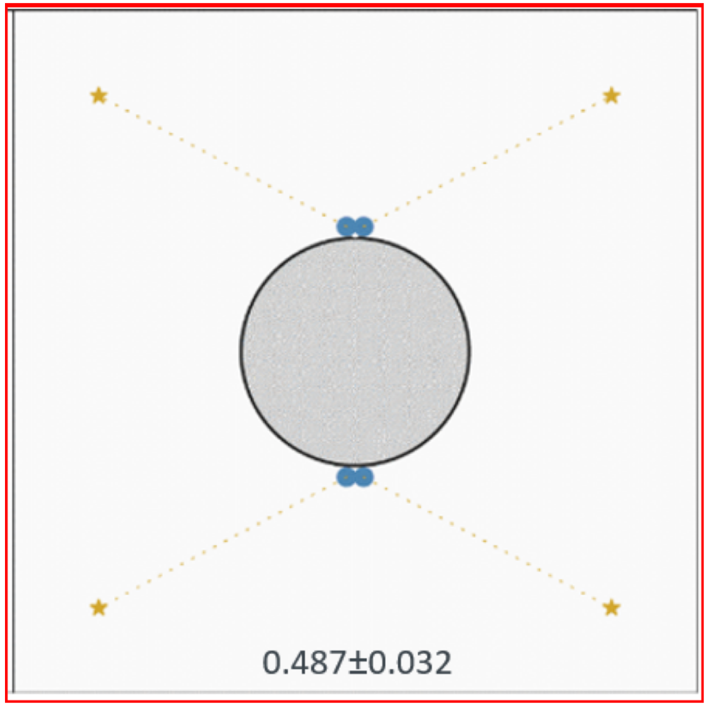
Result of planning for LGS option selection

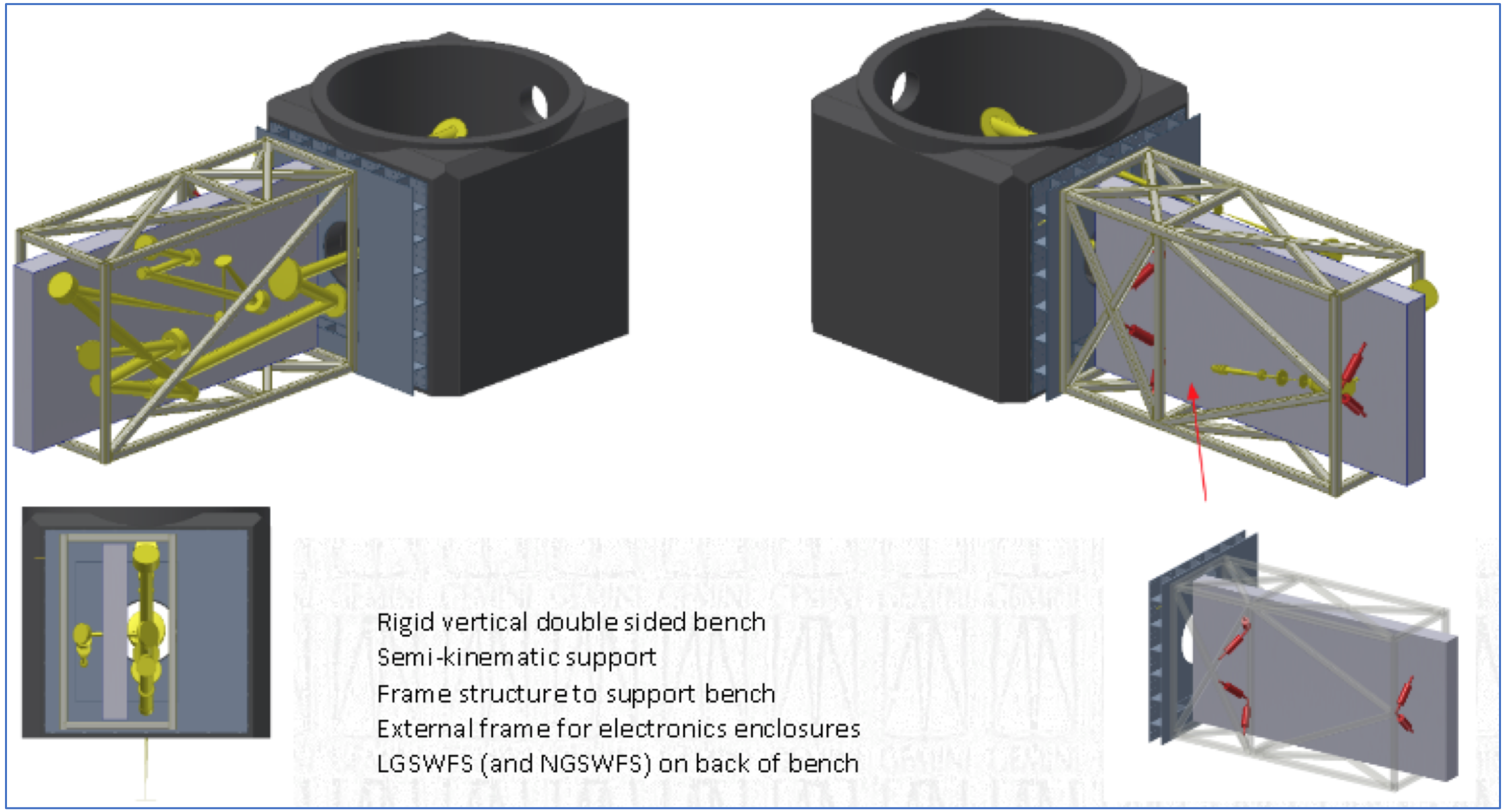
- Given our planning, LGS option 2/4/4 is the one that fits within our current funding envelope.
- We believe that we can marginally meet our requirements with this option, but with no headroom.
- As we do the 2/4/4 design and implementation, we will provide a ready post-GEMMA upgrade path to either 3/5/5 or 3/6/6. Benefits would include improved performance and support for future ground-layer AO use.



The Adaptive Optics Subsystem (AOS)

The Adaptive Optics Subsystem (AOS), sometimes also referred to as the AO Bench (AOB), will measure wavefront aberrations introduced mostly by the atmosphere and apply corrections for these aberrations.

- Since the AOS needs to handle multiple LGSs and NGSs, as in the previous slides, the design and implementation of the AOS is very challenging, particularly within Gemini's volume and mass constraints.
- To help envision this, concepts of the optical path and mechanical mounting for the AOS are shown below. For reference, the ISS, the dark gray cube, is about 1.6m on a side.



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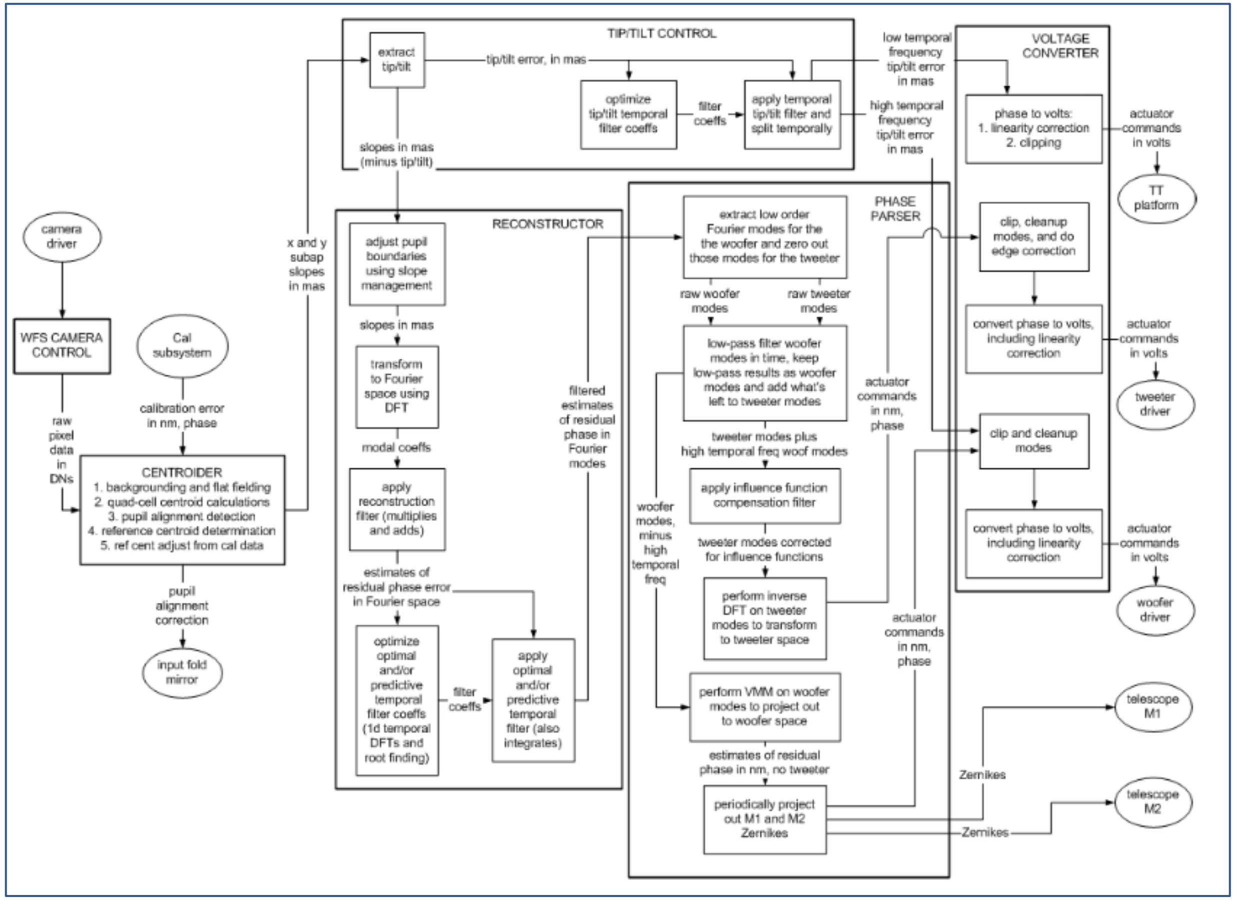
The Real-Time Computer (RTC)

The Real-Time Computer (RTC) reads the wavefront sensors (WFSs), calculates corrections, and outputs those corrections to the deformable mirrors (DMs) and tip/tilt (TT) mirror, all at 500 frames per second (fps) or faster.

- A huge amount of I/O (input/output) needs to occur and large numbers of calculations need to be done per second.
- Other functions need to be performed (interfacing with the outside world; providing streams of data; and updating wavefront reconstruction matrices).
- We will use state-of-the-art interface hardware and computer servers.
- The RTC will be made modular.
- Taking advantage of that modularity, we will deliver a new RTC implementation for GeMS.



Example RTC Hard Real-Time Data Flow (from GPI project)

Topics

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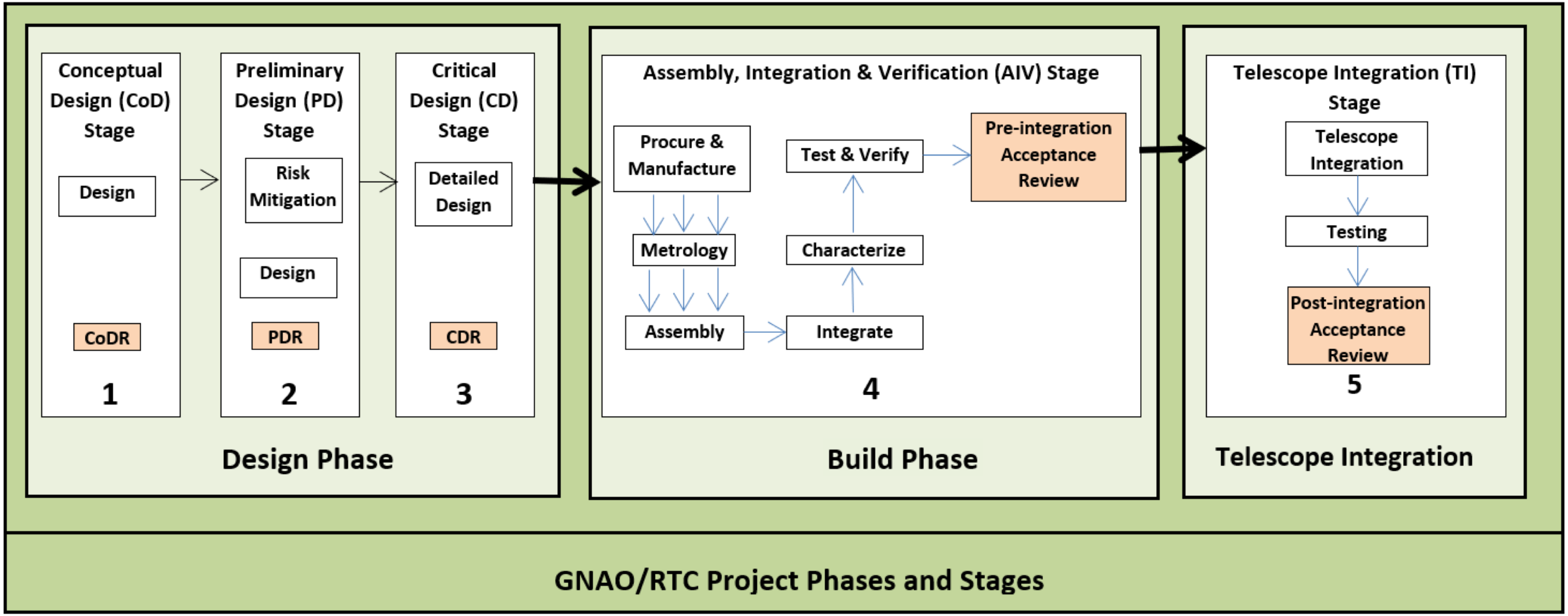
Overall GNAO/RTC Development Approach

Overall GNAO/RTC approach:

- Have Gemini serve as “prime contractor” and then:
- Do the LGS subsystem in-house – buy components, but do the design and implementation in-house.
- Subcontract out the AO subsystem – subcontract with a qualified external vendor.
- Use a hybrid approach for the RTC – utilize an existing code package, but procure the hardware platform and tailor the software package in-house.

GNAO/RTC Project Structure

The GNAO/RTC project will be divided into 3 phases and 5 stages as follows:



GNAO/RTC Scope

- The GEMMA NSF CSA award will fund the **GNAO/RTC** project from its planning stage through its first-light astronomical image, concluding at completion of I&T.
    - We will complete a Commissioning plan as part of the current GNAO/RTC funding.

- The **GNAO/RTC** project will continue beyond first-light, with O&M funding, to execute Commissioning.

- Except for integrating and testing with it, the **GNAOI** instrument is outside the scope the GNAO/RTC project.

- An **Adaptive Secondary Mirror (ASM)** is being considered as a separate project, using other funding -- the GNAO/RTC project will not preclude the use of it in the future.

Work Breakdown Structure (WBS), Top Level

WBS #	WBS Title	Deliverable	Responsible Organization
1.1	Meetings and Milestones	reviews and other project meetings	Gemini
1.2	Project Management, including non-subsystem-specific SE	management and SE products	Gemini
1.3	Science, including the AOWG	Sciences cases, science requirements, and consultation	Gemini
1.4	Laser Guide Star Subsystem (LGS)	LGS subsystem	Gemini
1.5	Adaptive Optics Subsystem (AOS)	AOS subsystem	Gemini and a to-be-selected subcontractor
1.6	Real-Time Computer (RTC)	RTC subsystem	Gemini and possibly a to-be-selected subcontractor

(please see WBS__GNAO_RTC.final_2_4_4 for much more detail)

Preliminary GNAO/RTC reviews schedule

GNAO/RTC reviews are preliminarily scheduled as in the following (please note that we have scheduled our CoDR for 9/26/19 and 9/27/19, as calendar conflicts prevented us from using our preliminary dates in the week of 9/16/19):

1	**GNAO/RTC Project**	**Mon 5/20/19**
1.1	**Meetings And Milestones**	**Thu 9/5/19**
1.1.1	Submit documentation for CoDR	Thu 9/5/19
1.1.2	CoDR	Tue 9/17/19
1.1.3	CoDR concludes, PD commences	Mon 9/30/19
1.1.4	Submit documentation for PDR	Wed 5/6/20
1.1.5	PDR	Mon 5/18/20
1.1.6	PDR concludes, CD commences	Fri 5/29/20
1.1.7	Submit documentation for CDR	Wed 1/6/21
1.1.8	CDR	Mon 1/18/21
1.1.9	CDR concludes, Build commences	Fri 1/29/21
1.1.10	Submit documents for Pre-I&T Review	Thu 9/8/22
1.1.11	Pre-I&T Review	Tue 9/20/22
1.1.12	Pre-I&T Review concludes, I&T commences	Mon 10/3/22
1.1.13	Final document review	Wed 3/27/24

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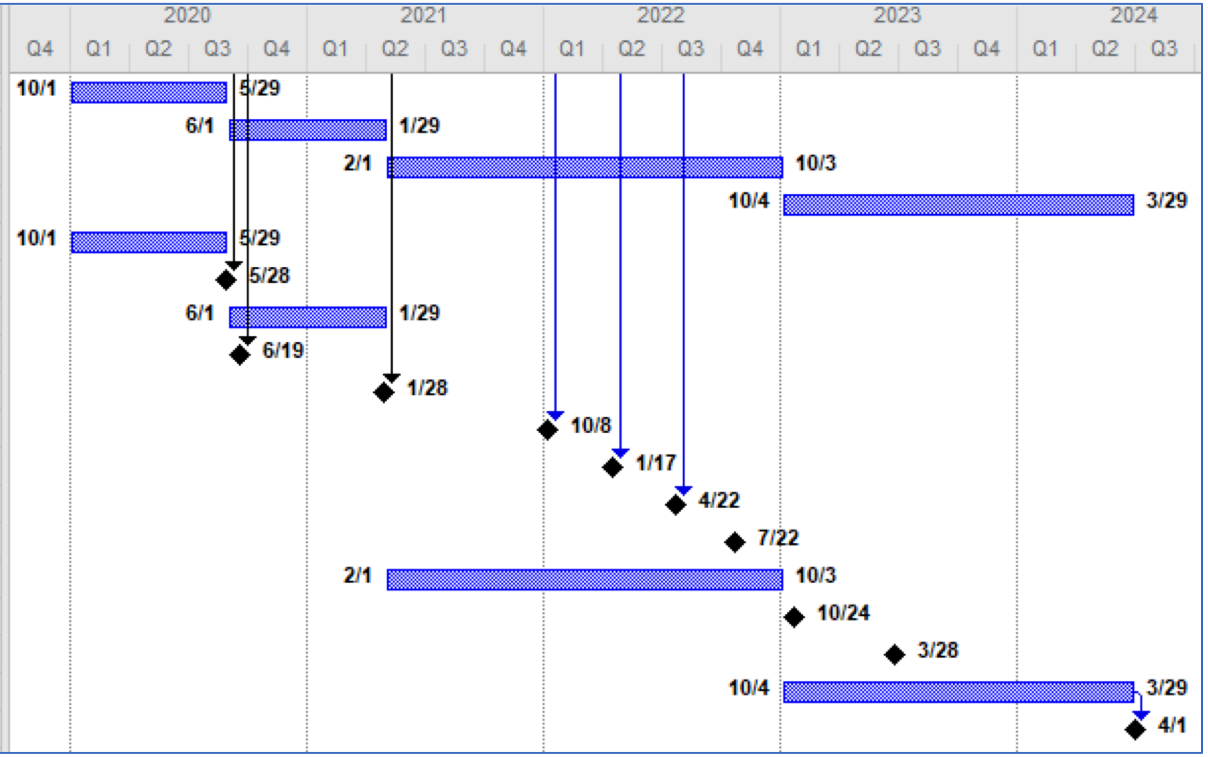
Project phases showing completions for subsystems

Task Name	Start
Overall project Preliminary Design	Tue 10/1/19
Overall project Critical Design	Mon 6/1/20
Overall project Build	Mon 2/1/21
Overall project I&T	Tue 10/4/22
AOS Preliminary Design	Tue 10/1/19
LGS PD concludes	Thu 5/28/20
AOS Critical Design	Mon 6/1/20
RTC design complete	Fri 6/19/20
LGS CD concludes	Thu 1/28/21
RTC -- GeMS RTC deployed	Fri 10/8/21
AOS control computer ready for integration	Mon 1/17/22
RTC -- GNAO RTC ready for integration	Fri 4/22/22
LGS laser system 1 installed and commissioned	Fri 7/22/22
AOS Build	Mon 2/1/21
LGS laser system 2 installed and commissioned	Mon 10/24/22
LGS control computer tested and ready	Tue 3/28/23
AOS I&T	Tue 10/4/22
First Light	Mon 4/1/24



- The project phases are shown in yellow.
- The AOS (to be subcontracted), follows those phases -- the AOS is shown in blue.
- The RTC, shown in green, will be phased to be ready for integration with the AOS during the AOS's build phase.

  The LGS subsystem, in orange, will be integrated onto the telescope and tested as its components are ready, to be prepared for the AOS integration early in I&T
- The bulk of the I&T phase will be dedicated to integrating the AOS and testing the system as a whole.

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Phasing With Fractions Of Project

Task Name	Start	Finish	Weeks	Fract of Project	Fract of PD through I&T
Project Planning	10/1/2018	12/31/2018	13.0	4.2%	
Conceptual Design	1/1/2019	9/30/2019	38.9	12.5%	
Preliminary Design	10/1/2019	5/29/2020	34.4	11.1%	14.8%
Critical Design	6/1/2020	1/29/2021	34.6	11.1%	14.8%
Build	2/1/2021	9/30/2022	86.6	27.8%	37.1%
Integration and Test	10/3/2022	3/29/2024	77.6	25.0%	33.3%
First Light	4/1/2024	4/1/2024	0.0	0.0%	
Schedule Contingency	4/2/2024	9/30/2024	25.9	8.3%	
Totals:			**310.9**	**1.0**	**1.0**

Basis of Estimate

In-House Work

- Solicited estimates from the experts in Gemini.
- Then sanity checked each other and against other projects as possible.
- Used all of the estimates to construct a fully resourced project plan for labor using MS Project.

Adaptive Optics Subsystem (AOS) Subcontract

- Requested Rough Order of Magnitude (ROM) estimates from 4 institutions skilled in the art of building AO systems.
  - Flowed-down top-level requirements to the AO subsystem in a preliminary sense.
  - Sent a Documentation Package to the prospective institutions.
  - All of the institutions responded. The summary is that we estimate that the AOS subcontract will cost approximately $4.36M.
  - This does not include expensive AOS components that Gemini would procure and provide.

RTC Subcontract

- Option 1: Start with an existing code package and adapt it to our needs in-house.
- Option 2: Subcontract with another institution to develop all or most of the RTC for us.
  - Requested Rough Order of Magnitude (ROM) estimates from 2 institutions experienced with RTC development.
  - Both responded. The summary is that we estimate that an RTC subcontract would cost approximately $2.2M.

Procurements

- Estimated costs based on: previous quotes (adjusting for inflation), recent interactions with prospective vendors, web-quotes, and/or experience with previous projects for lower-cost items.

GNAO/RTC End-of-project Deliverables

The end-of-project GNAO/RTC Deliverables currently include:

- GNAO/RTC Facility
- GNAO/RTC Documentation Set
- GNAO/RTC Facility Associated Hardware
- GNAO/RTC Facility Associated Software
- Relevant Observatory Infrastructure Upgrades
- Relevant Observatory Control System Upgrades
- Staff GNAO/RTC Training

GNAO/RTC Labor by Fiscal Year

LABOR COSTS	FY19	FY20	FY21	FY22	FY23	FY24	TOTAL
Engineering	$317,688	$448,756	$426,911	$249,615	$221,347	$119,255	**$1,783,572**
Management	$114,448	$353,645	$304,691	$259,560	$72,913	$57,577	**$1,162,834**
Postdocs	$21,887	$133,300	$92,879	$67,590	$44,984	$27,579	**$388,218**
Project Support	$7,515	$21,815	$22,469	$23,143	$23,069	$13,464	**$111,475**
Scientists	$98,747	$244,961	$191,815	$167,175	$84,529	$49,982	**$837,209**
Systems Engineering	$154,403	$428,828	$413,904	$284,717	$195,505	$107,078	**$1,584,436**
SOS	$2,294	$0	$0	$0	$0	$0	**$2,294**
Software Engineering	$45,994	$96,381	$102,638	$84,920	$49,982	$3,677	**$383,593**
Technicians	$0	$0	$120,499	$154,248	$0	$0	**$274,747**
Grand Total	**$762,976**	**$1,727,686**	**$1,675,806**	**$1,290,969**	**$692,329**	**$378,613**	**$6,528,378**

(includes 22% complexity)

GNAO/RTC Budget by Fiscal Year, 1 of 2

WBS #	Labor	FY19	FY20	FY21	FY22	FY23	FY24	Total
1.1	Meetings And Milestones	$31,169	$31,169	$31,169	$31,169	$0	$31,169	**$155,846**
1.2	Project Management, including non-subsystem-specific SE	$139,054	$428,431	$350,360	$300,546	$109,246	$73,259	**$1,400,897**
1.3	Science, including the AOWG	$88,173	$217,988	$164,183	$153,604	$92,774	$47,428	**$764,149**
1.4	Laser Guide Star Subsystem (LGS)	$245,820	$541,645	$655,755	$500,656	$277,238	$109,197	**$2,330,311**
1.5	Adaptive Optics Subsystem (AOS)	$188,060	$245,788	$255,614	$132,791	$115,211	$64,451	**$1,001,914**
1.6	Real-Time Computer (RTC)	$70,699	$262,663	$218,726	$172,203	$97,860	$53,108	**$875,260**
	Non-Labor							
1.4	Laser Guide Star Subsystem (LGS)	$0	$372,026	$1,444,500	$2,185,661	$0	$0	**$4,002,187**
1.5	Adaptive Optics Subsystem (AOS)	$0	$826,546	$3,158,196	$0	$2,126,042	$1,594,532	**$7,705,316**
1.6	Real-Time Computer (RTC)	$0	$156,160	$0	$100,040	$0	$0	**$256,200**
	Other							
other	Spent to date	$288,574	$0	$0	$0	$0	$0	**$288,574**
other	Travel	$54,158	$102,096	$88,902	$52,797	$29,804	$53,732	**$381,489**
other	Supplies	$2,288	$6,863	$6,863	$6,863	$6,863	$6,863	**$36,600**
other	Freight	$0	$0	$0	$0	$48,800	$0	**$48,800**
	Totals	**$1,107,995**	**$3,191,376**	**$6,374,267**	**$3,636,329**	**$2,903,837**	**$2,033,739**	**$19,247,544**

(includes 22% complexity as appropriate)

GNAO/RTC Budget by Fiscal Year, 2 of 2

	FY19	FY20	FY21	FY22	FY23	FY24	Total
Spent to date	$288,574	$0	$0	$0	$0	$0	**$288,574**
Labor	$762,976	$1,727,686	$1,675,806	$1,290,969	$692,329	$378,613	**$6,528,378**
Procurements	$0	$528,186	$3,805,430	$2,285,701	$0	$0	**$6,619,317**
Contracts	$0	$826,546	$797,266	$0	$2,126,042	$1,594,532	**$5,344,386**
Travel	$54,158	$102,096	$88,902	$52,797	$29,804	$53,732	**$381,489**
Supplies	$2,288	$6,863	$6,863	$6,863	$6,863	$6,863	**$36,600**
Freight	$0	$0	$0	$0	$48,800	$0	**$48,800**
Total	**$1,107,995**	**$3,191,376**	**$6,374,267**	**$3,636,329**	**$2,903,837**	**$2,033,739**	**$19,247,544**

(includes 22% complexity as appropriate)

GNAO/RTC Phased Procurements

Please note that the phased procurements shown below will require ordering and partially paying for some items prior to the conclusion of our Design Phases, the laser and LLTs in particular.

		PD		CD			Build							I&T						First Light
	Phase starts	**10/1/2019**		**6/1/2020**			**2/1/2021**							**10/3/2022**						**4/1/2024**
	Calendar year:	CA19	CA20	CA20	CA20	CA20	CA21	CA21	CA21	CA21	CA22	CA22	CA22	CA22	CA23	CA23	CA23	CA23	CA24	CA24
	Fiscal year:	FY20	FY20	FY20	FY20	FY21	FY21	FY21	FY21	FY22	FY22	FY22	FY22	FY23	FY23	FY23	FY23	FY24	FY24	FY24
Item	**Need By**																			
lasers	11/2/2021	$372,026								$868,061										
4 LLTs	10/4/21, 12/20/21, 2/16/22, 3/2/22					$518,500	$518,500			$518,500	$518,500									
heat exchangers	2/8/2021						$109,800													
optical tables for BTOs	5/3/2021							$5,856												
optics for BTOs	5/3/2021							$15,860												
BTOs enclosure	5/3/2021							$85,400												
motors for BTOs	5/3/2021							$29,280												
FSMs for lasers	5/3/2021							$57,238												
motor controller for BTOs	5/3/2021							$26,840												
laser pointing camera	5/3/2021							$48,800												
beam diagnostic systems	5/3/2021							$15,860												
safety equipment	3/7/2022						$5,978													
telescope mounting hdw	3/7/2022										$146,400									
telescope demo, etc.	3/7/2022										$134,200									
Control computer	2/1/2021						$6,588													
DM0	1sr Q in build						$421,583													
drive electronics for DM0	1sr Q in build						$171,758													
DM1	1sr Q in build						$0													
drive electronics for DM1	1sr Q in build						$0													
DM2	1sr Q in build						$421,583													
drive electronics for DM2	1sr Q in build						$171,758													
TT stage/mirror	1sr Q in build						$89,378													
TT mirror	1sr Q in build						$173,237													
LGS WFS cameras	1sr Q in build						$837,884													
NGS WFS camera	1sr Q in build						$70,455													
Control computer	1sr Q in build						$3,294													
Flatwavefronts	PD and CD	$14,640		$14,640																
AOS Subcontract	PD through I&T			$797,266			$797,266							$2,126,042						$1,594,532
RTC computer		$112,240								$56,120										
AO interface electronics			$43,920							$43,920										
Total:		**$498,906**	**$43,920**	**$811,906**		**$518,500**	**$3,799,062**	**$285,134**		**$1,486,601**	**$799,100**			**$2,126,042**						**$1,594,532**

(includes 22% complexity)

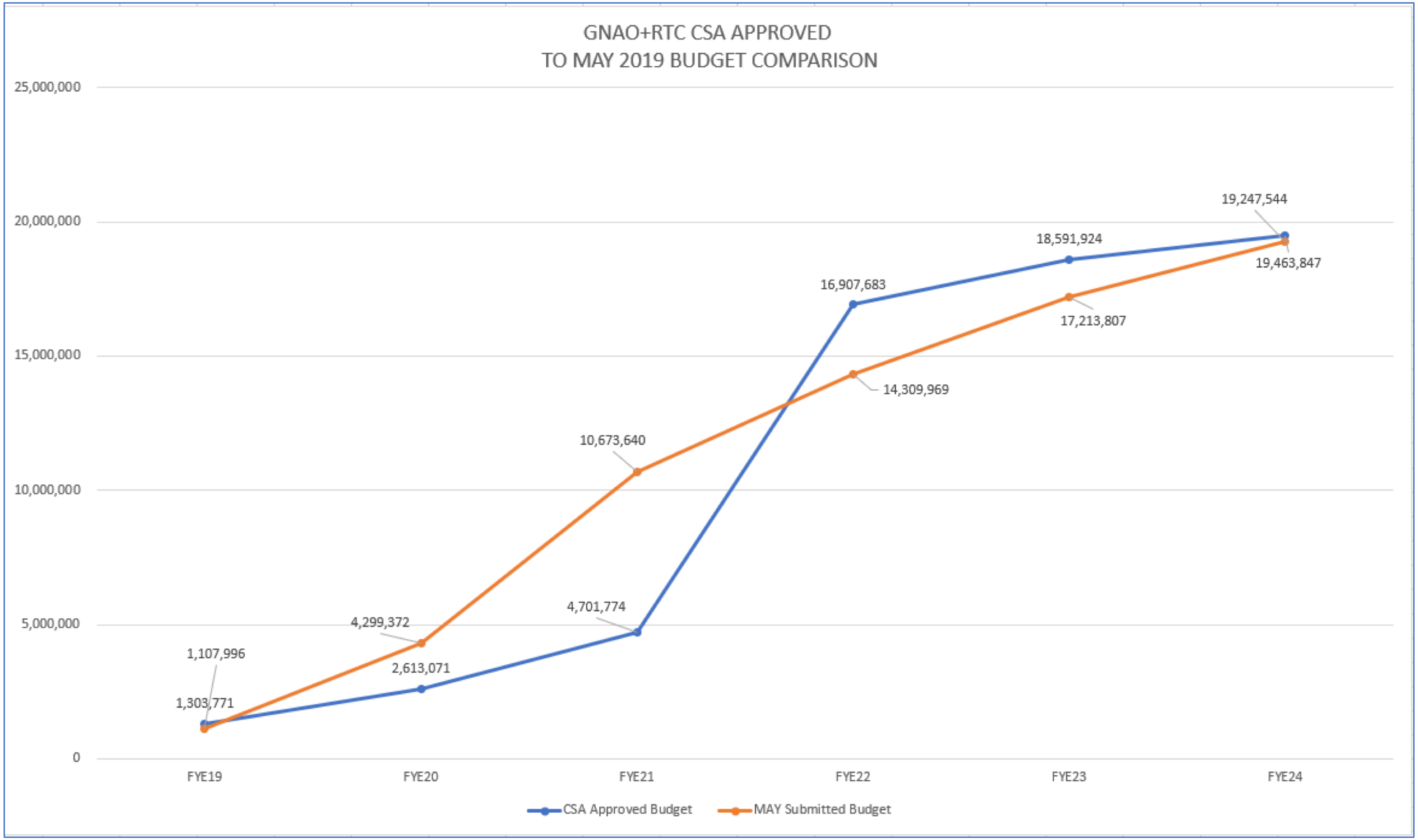
GNAO/RTC Budget by WBS Element

WBS #	Description	Total	Labor	Procures	Contracts	Travel, etc.	Notes
1.1	Meetings And Milestones	$155,846	$155,846				this is the labor to participate in review meetings, etc.
1.2	Project Management, including non-subsystem-specific SE	$1,400,897	$1,400,897				
1.3	Science, including the AOWG	$764,149	$764,149				
1.4	Laser Guide Star Subsystem (LGS)	$6,332,498	$2,330,311				this is the labor to do the LGS in-house with the the 2/4/4 option (2 lasers, 4 LLTs, 4 spots) in the 2-2-0 configuration
				$4,002,187			these are the procurements to support the 2/4/4 option (2 lasers, 4 LLTs, 4 spots) -- we already have 1 laser, so we need 1 more laser and 4 LLTs
1.5	Adaptive Optics Subsystem (AOS)	$8,707,230	$1,001,914				this is for Systems Engineering and Control Computer software development
				$2,360,931			this is for the fast active AO components that we said we would provide when requesting ROMs, to support the 2/4/4 option
					$29,280		small contracts with Flatwavefronts for AO simulations
					$5,315,106		this is the estimated cost of the AOS subcontract, as per the ROM estimates that we requested and received
1.6	Real-Time Computer (RTC)	$1,131,460	$875,260				this is for labor to develop the RTC in-house starting with an open-source AO software package
				$256,200			these are the prcurements to develop the RTC in-house
other	Estimated spending to May 31, 2019	$288,574				$288,574	based on actuals of $216,829.28 to early May; our in-depth plan starts on June 1, 2019
other	Travel expenses	$381,489				$381,489	
other	Supplies	$36,600				$36,600	
other	Freight	$48,800				$48,800	
	Total total	$19,247,544	$6,528,378	$6,619,317	$5,344,386	$755,463	

(includes 22% complexity as appropriate)

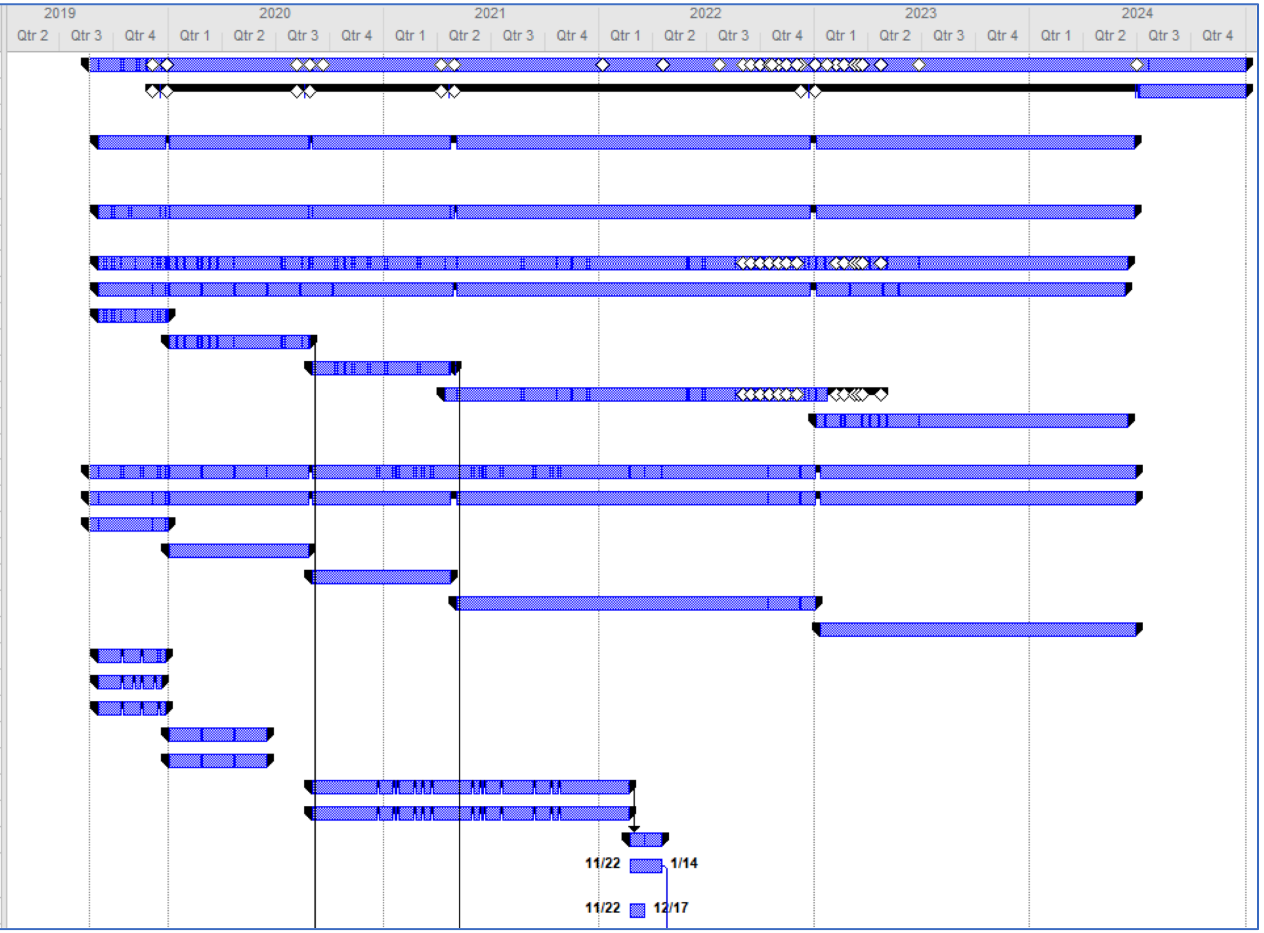
PEP page 41 (Table

GNAO/RTC FY Budget, Cumulative



GNAO/RTC resource-loaded project schedule, 1 of 2

	WBS	Task Name	Start	Finish	Work
1	1	GNAO/RTC Project	Mon 5/20/19	Tue 10/1/24	73,038.87 hrs
2	1.1	Meetings And Milestones	Thu 9/5/19	Tue 10/1/24	1,632 hrs
18					
19	1.2	Project Management, including non-subsystem-specific SE	Mon 6/3/19	Mon 3/25/24	13,686.89 hrs
69					
70	1.3	Science, including the AOWG	Mon 6/3/19	Mon 3/25/24	9,464 hrs
115					
116	1.4	Laser Guide Star Subsystem (LGS)	Mon 6/3/19	Fri 3/15/24	26,688.24 hrs
117	1.4.1	LGS Systems Engineering	Mon 6/3/19	Mon 3/11/24	8,396.86 hrs
158	1.4.2	Conceptual Design	Mon 6/3/19	Mon 9/30/19	1,436 hrs
178	1.4.3	Preliminary Design	Tue 10/1/19	Thu 5/28/20	2,602.2 hrs
209	1.4.4	Critical Design	Mon 6/1/20	Thu 1/28/21	3,488.4 hrs
240	1.4.5	Build	Mon 1/11/21	Sat 1/21/23	8,884.77 hrs
332	1.4.6	Integrate and Test (I&T)	Tue 10/4/22	Fri 3/15/24	1,880 hrs
343					
344	1.5	Adaptive Optics Subsystem (AOS) (mostly a subcontract)	Mon 5/20/19	Fri 3/29/24	10,739.74 hrs
345	1.5.1	AOS System Engineering	Mon 5/20/19	Fri 3/29/24	5,559.74 hrs
346	1.5.1.1	Conceptual Design	Mon 5/20/19	Mon 9/30/19	1,825.74 hrs
371	1.5.1.2	Preliminary (subcontract)	Tue 10/1/19	Mon 5/25/20	272 hrs
373	1.5.1.3	Critical Design (subcontract)	Mon 6/1/20	Fri 1/22/21	272 hrs
375	1.5.1.4	Build (subcontract)	Mon 2/1/21	Mon 10/3/22	880 hrs
380	1.5.1.5	Integration and Testing (I&T)	Mon 10/10/22	Fri 3/29/24	2,310 hrs
382	1.5.2	Conceptual Design	Mon 6/3/19	Fri 9/27/19	660 hrs
383	1.5.2.1	Optical Engineering	Mon 6/3/19	Fri 9/20/19	320 hrs
389	1.5.2.2	Mechanical Engineering	Mon 6/3/19	Fri 9/27/19	340 hrs
394	1.5.3	Preliminary Design	Tue 10/1/19	Mon 3/16/20	960 hrs
395	1.5.3.1	Control Computer Software	Tue 10/1/19	Mon 3/16/20	960 hrs
399	1.5.4	Critical Design	Mon 6/1/20	Fri 11/19/21	3,080 hrs
400	1.5.4.1	Control Computer Software	Mon 6/1/20	Fri 11/19/21	3,080 hrs
416	1.5.5	Build / Implement / Incrementally Integrate & Test	Mon 11/22/21	Fri 1/14/22	480 hrs
417	1.5.5.1	Control Computer Software Testing of Mechanical Components	Mon 11/22/21	Fri 1/14/22	320 hrs
418	1.5.5.2	Finalize And Perform Acceptance Tests	Mon 11/22/21	Fri 12/17/21	160 hrs



(please see WBS__GNAO_RTC.final_2_4_4 for much more detail)

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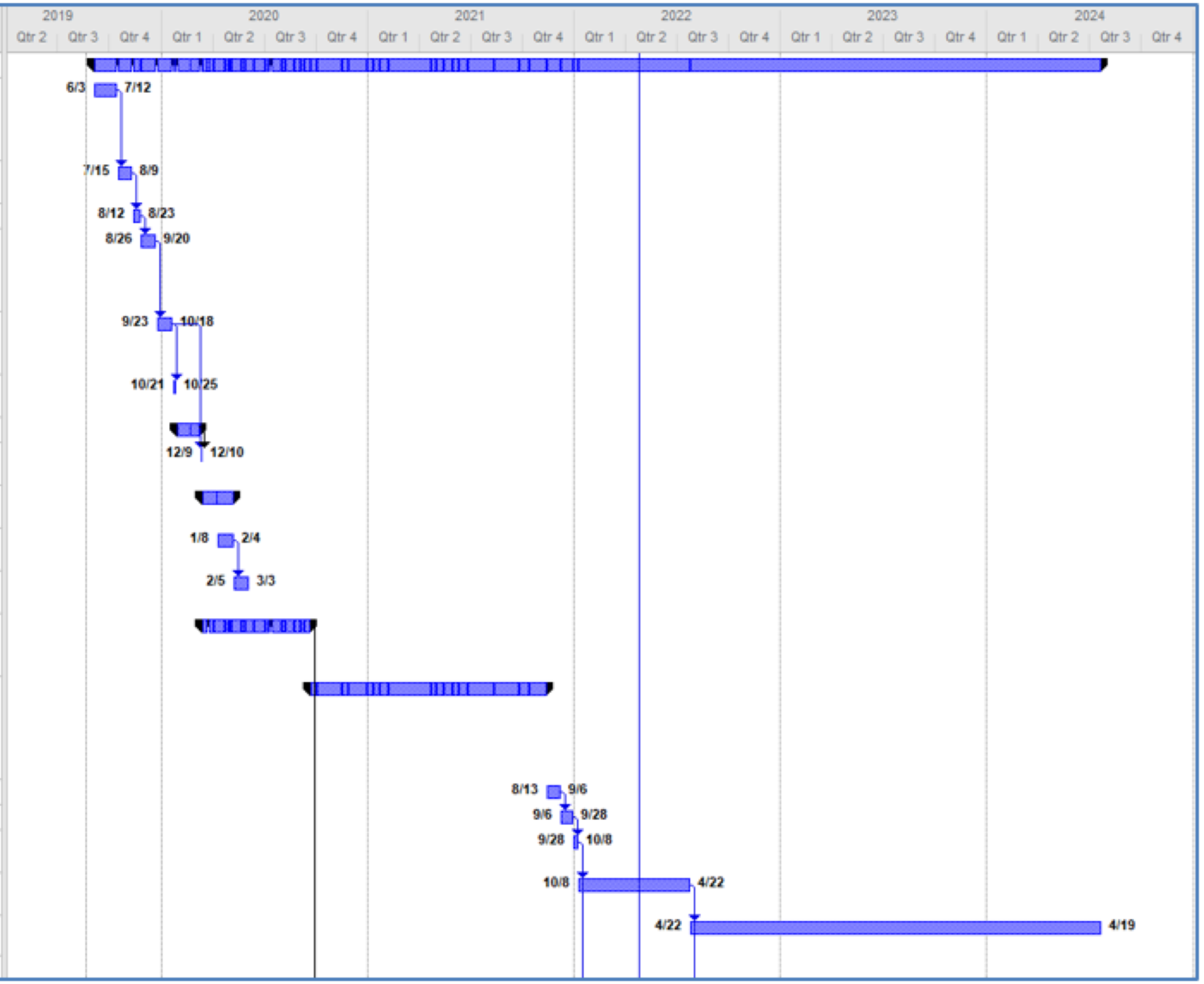
GNAO/RTC resource-loaded project schedule, 2 of 2

	WBS	Task Name	Start	Finish	Work
420	**1.6**	**Real-Time Computer (RTC)**	**Mon 6/3/19**	**Fri 4/19/24**	**10,828 hrs**
421	1.6.1	Flow-down GNAO / GeMS system requirements to the RTC and generate RTC Functional Requirements and compare against existing GN and GS LGS requirements.	Mon 6/3/19	Fri 7/12/19	120 hrs
422	1.6.2	Write a draft of the final test document to assure that the requirements can be tested against.	Mon 7/15/19	Fri 8/9/19	80 hrs
423	1.6.3	Design external RTC interfaces and generate ICDs.	Mon 8/12/19	Fri 8/23/19	100 hrs
424	1.6.4	Start a Design Document and Users Manual to serve as input to the CoDR documentation package (and to be kept up to date as the project progresses).	Mon 8/26/19	Fri 9/20/19	176 hrs
425	1.6.5	Select an existing AO RTC software package to serve as the baseline for RTC software development.	Mon 9/23/19	Fri 10/18/19	160 hrs
426	1.6.6	Participate in AO RTC package training (this is a training place holder).	Mon 10/21/19	Fri 10/25/19	120 hrs
427	**1.6.7**	**Select computer harware for GeMS**	**Mon 10/28/19**	**Fri 12/6/19**	**296 hrs**
430	1.6.8	Hold a special review of the software package and hardware selections.	Mon 12/9/19	Tue 12/10/19	64 hrs
431	**1.6.9**	**Procure software package and hardware selected so far.**	**Wed 12/11/19**	**Tue 2/4/20**	**64 hrs**
435	1.6.10	Bring up the GeMS hardware platform and optimize for performance.	Wed 1/8/20	Tue 2/4/20	80 hrs
436	1.6.11	Instal drivers for GeMS AO peripherals and test, as hardware becomes available.	Wed 2/5/20	Tue 3/3/20	80 hrs
437	**1.6.12**	**Design AO RTC package adaptation to GeMS and new code as needed. This is the design phase for RTC software.**	**Wed 12/11/19**	**Fri 6/19/20**	**1,648 hrs**
455	**1.6.13**	**Implement and test code to provide GeMS functionality as designed in the previous set of tasks. This is the implementation and testing phase for the RTC software (not to be confused with Integration and Test).**	**Fri 6/19/20**	**Fri 8/13/21**	**3,600 hrs**
473	1.6.14	Finalize the final test document and execute it.	Fri 8/13/21	Mon 9/6/21	192 hrs
474	1.6.15	Finalize all documentation and release.	Mon 9/6/21	Tue 9/28/21	192 hrs
475	1.6.16	Support GeMS integration and first-light (with the new RTC).	Tue 9/28/21	Fri 10/8/21	96 hrs
476	1.6.17	Procure the hardware for GNAO and port the RTC, as developed above, to GNAO.	Fri 10/8/21	Fri 4/22/22	1,680 hrs
477	1.6.18	Provide ongoing support through build and integration	Fri 4/22/22	Fri 4/19/24	2,080 hrs
478					



(please see WBS__GNAO_RTC.final_2_4_4 for much more detail)

Earned Value Analysis (EVA)

- Earned Value Analysis (EVA) will be used to track the project from both labor cost and schedule perspectives.
- The Cost Performance Index (CPI) and Schedule Performance Index (SPI) will be tracked down to the discipline level for each subsystem.

- When management, systems engineering, and science are included, this will result in 19 elements that will be tracked.
- Labor will be tracked to these levels using a Gemini account number for each.

- Actual costs and % completes will be entered, to update and report CPI and SPI, on a monthly basis.
- The requirement to use EVA in this manner and at the same frequency (monthly) will be flowed down to our subcontractors.

- A complication for EVA is that we have been instructed to include complexity in our plan on a per-line basis. If we left complexity included when calculating EVA, CPI would appear very off even if the project were running perfectly to plan. Therefore, we will need to remove complexity when calculating EVA.

Gemini's Request to NSF

For purposes of project management, we expect to hold the 22% complexity factor as a separate reserve going forward, instead at the line-by-line project level (as it is currently).

GNAO/RTC Staffing Plan

The table below shows GNAO/RTC's labor needs in FTE-fractions per FY (assuming 1720 hours per year) by labor category. "Software Engineer" is highlighted in yellow because that was our only pressing need when the PEP was produced. That need has been resolved.

FTEs	FY19	FY20	FY21	FY22	FY23	FY24	TOTAL
Engineering	2.10	2.88	2.66	1.51	1.30	0.68	**11.13**
Management	0.53	1.59	1.33	1.10	0.30	0.23	**5.08**
Postdocs	0.23	1.36	0.92	0.65	0.42	0.25	**3.83**
Project Support	0.11	0.31	0.31	0.31	0.30	0.17	**1.51**
Scientists	0.71	1.71	1.30	1.10	0.54	0.31	**5.67**
Systems Engineering	1.12	3.02	2.83	1.89	1.26	0.67	**10.79**
SOS	0.02	0.00	0.00	0.00	0.00	0.00	**0.02**
Software Engineering	0.29	0.59	0.61	0.49	0.28	0.02	**2.28**
Technicians	0.00	0.00	0.98	1.22	0.00	0.00	**2.20**
Grand Total	**5.11**	**11.46**	**10.94**	**8.27**	**4.40**	**2.33**	**42.51**

Hiring and Staff Transition Plan

Significant progress has been made in staffing:

- Senior Project Manager hired (David Palmer);
- Principal Investigator designated (Gaetano Sivo);
- Subcontract Manager hired (Celia Blain);
- Project Scientist designated (Julia Scharwächter);
- Sr. System Engineer hired (William Rambold, through a staffing agency due to his current location);
- Postdoc hired (David Jenkins, starting in July); and
- A combination of people already involved with the project will serve as AO Scientist (Gaetano Sivo, Celia Blain, Laure Catala (a postdoc), and Marcos van Dam (a contractor we have worked with frequently in the past)).

Change and Document Control Plans

Change Control Plan

- All changes to the project will be requested through a Change Request Form to the Project Manager.
- We will institute a change control board (CCB) consisting of at least the PM, PI, and SE.
- Budget or schedule thresholds would need Executive Committee Chair concurrence:
  - greater than $200k for cost or greater than one month for schedule.
- All changes will be reported to the Executive Committee Chair, regardless of size.

Documentation Control Plan

- Project documents will go under change control as listed in the next slide: "*GNAO/RTC Documentation Set With CC Indicated*".
- Once under change control, the same CCB described above will need to approve changes.
- To physically control documents, we will use Gemini's Document Management Tool (DMT).

GNAO/RTC Documentation Set, With CC Indicated

	Doc No.	Deliverable	Stage					
			CoD	PD	CD	AIV	TTI	~~CSV~~
Design	GNAO-01	Project Management Plan (PMP)	✓cc	✓	✓	✓	✓	
Design	GNAO-02	System Engineering Management Plan (SEMP)	✓cc	✓	✓	✓	✓	
Design	GNAO-03	Safety Management Plan (SMP)	✓cc	✓	✓	✓	✓	
Design	GNAO-04	Science Cases	✓cc	✓	✓	✓	✓	~~✓~~
Design	GNAO-05	Concept of Operations Document (ConOps)	✓cc	✓	✓	✓	✓	~~✓~~
Design	GNAO-06	Requirements Document (RD)	✓	✓	✓	✓	✓	~~✓~~
Design	GNAO-07	Conceptual Design Document (CoDD)	✓					
Design	GNAO-08	CoD End Stage Report	✓					
Design	GNAO-10	Preliminary Design Document (PDD)		✓				
Design	GNAO-11	Facility Interface Control Documents (ICD)		✓D	✓cc	✓	✓	~~✓~~
Design	GNAO-12	Acceptance Test Plan (ATP)		✓D	✓cc			
Design	GNAO-13	PD End Stage Report		✓				
Design	GNAO-15	Critical Design Document (CDD)			✓			
Design	GNAO-16	Assembly, Integration and Verification Plan			✓			
Design	GNAO-17	CD End Stage Report			✓			
Build	GNAO-19	As-built records				✓cc	✓	~~✓~~
Build	GNAO-20	Recommended Spares List				✓cc	✓	~~✓~~
Build	GNAO-21	Pre-Integration Acceptance Test Report (pre-ATR)				✓		
Build	GNAO-22	Service and Maintenance Manual (S&MM)				✓cc	✓	~~✓~~
Build	GNAO-23	User Manual (UM)				✓cc	✓	~~✓~~
Build	GNAO-24	Technical Manual (TM)				✓cc	✓	~~✓~~
Build	GNAO-25	Software Maintenance Manual (SMM)				✓cc	✓	~~✓~~
Build	GNAO-26	Commissioning & Science Verification Plan (CSVP)				✓D	✓cc	
Build	GNAO-28	AIV End Stage Report				✓		
Telescope Int. & Comm.	GNAO-30	Post-Integration Acceptance Test Report (post-ATR)					✓	
Telescope Int. & Comm.	GNAO-31	TI End Stage Report					✓	
Telescope Int. & Comm.	GNAO-32	C&SV Stage Plan					✓	
Telescope Int. & Comm.	~~GNAO-33~~	~~Commissioning and Science Verification Report (CSVR)~~						~~✓~~
Telescope Int. & Comm.	~~GNAO-34~~	~~GNAO End Project Report~~						~~✓~~

[cc] Change Control [D] Draft

Topics

- Introduction.
- Brief technical description for context.
- In-depth project plan.
- **Risks.**
- Systems Engineering plan.
- Summary.

Updated Risk Register, 1 of 2

Part I. Risk Identification						Part II. Risk Analysis for Existing Controls			
Name	Project Risk Category	Risk Description (ignoring controls) [use: if, because, then]	Impact 1-5 (ignoring controls)	Likelihood 1-5 (ignoring controls)	Total Risk Score Low = 1 - 8 Med = 9 - 16 High = 17 - 25	What Controls (if any) are currently in place?	Control Effectiveness 1-5	Residual Risk Score Low = 1 - 8 Med = 9 - 16 High = 17 - 25	Control or Risk Mitigation Strategy
Internal resource shortage	Resources	If the current team is allocated to other projects then the project may fall behind schedule	4	5	20	The project has been made the highest priority at the Observatory (even above operations); we are leaving "Control Effectiveness" set to 3 until we see the practical effect of this highest priority mandate	3	10	More assertively enforce highest priority mandate. More aggressively hire and train replacements for GNAO/RTC team members. Assign a dedicated team or firmly dedicated percentages of team members.
Late GNAOI interface / integration requirements (since it is outside the	Technical	If the requirements are not developed and the interfaces cannot be completed in a timely manner the project completion will not be met.	3	3	9	The GNAOI is in process.	2	2	Bring GSAOI up from south to use in place of GNAOI temporarily
Procurements	Schedule	If procurements are not comleted in a timely manner the schedule will slip.	5	4	20	A phased procurement strategy has been developed, in conversation with long-lead-time vendors, and will be implemented as we conclude CoD; this is still a relatively likely risk, none-the-less, given the time frame of the project	3	10	Explore ways to expedite the procurement process and possible alternate vendors
Vendor Delays	Technical	If the strategy to procure major (non off-the-shelf) subassemblies from different vendors is delayed, then this may impact schedule and budget.	3	3	9	We have been in conversation with potential vendors; this is still a relatively likely risk, none-the-less, given the time frame of the project	3	5	
AOS subcontract	Schedule	If we cannot get an AOS subcontract in place very quickly due to everyting that goes into letting such a contract, inlcuding approvals, we may not receive the AOS in time to complete our project on schedule.	5	4	20	Perform all or part of the Preliminary Design in-house, supplementing with external resources, until a contract is in place and then work collaboratively with subcontractor for the remainder of PD.	4	15	Request quick turn-around for NSF approvals. Request that we be able to use one or more time and materials contracts.

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Updated Risk Register, 2 of 2

Part I. Risk Identification						Part II. Risk Analysis for Existing Controls			
Name	Project Risk Category	Risk Description (ignoring controls) [use: if, because, then]	Impact 1-5 (ignoring controls)	Likelihood 1-5 (ignoring controls)	Total Risk Score Low = 1 - 8 Med = 9 - 16 High = 17 - 25	What Controls (if any) are currently in place?	Control Effectiveness 1-5	Residual Risk Score Low = 1 - 8 Med = 9 - 16 High = 17 - 25	Control or Risk Mitigation Strategy
Legacy hardware interfaces for GeMS RTC	Schedule	If there is insufficient information on legacy hardware to implement interfaces to the new RTC, then the schedule may be impacted.	4	4	16	Begin evaluating interfaces early	3	8	
Tight design phase schedule and resources precluding following system engineering processes	Quality	If the design processes outlined in the GNAO SEMP are skipped or minimized because of resource and/or schedule constraints, then the quality of the deliverable could be compromised.	4	3	12	Identify and apply additional SE resources	4	9	
RTC Resources	Resources	If the RTC is designed in-house because of budget constraints, then the RTC could be delivered behind schedule due to insufficient in-house resources.	4	3	12	Pursue a trade study and RFP to evaluate external options.			
Number of Lasers	Technical	If only 2 Lasers are available because of budget constraints, then the top level performance requirements may not be met.	3	2	6	Ensure upscope options for additional LGS are accounted for in design. Escalate risk to observatory	2	2	
M2 Print-Through	Technical	If the existing GN M2 print-through limitation is not addressed, then the performance requirements may not be met over the elevation range.	4	4	16	Analyze limitations of print-through impact on performance. Escalate risk to observatory.			

National Science Foundation

AURA

Gemini's Request to NSF

We ask the NSF to join with Gemini staff and governance to expedite the approvals for procurements that will affect the GNAO/RTC schedule (~4-5 critical procurements). We request that NSF strive for a expedited turnaround time (e.g. 10 business days) for these critical reviews and approvals.

We ask NSF to review a contract for the long-lead procurement for the TOPTICA laser(s) at the time of GNAO/RTC CoDR (September/October 2019).

Topics

- Introduction.
- Brief technical description for context.
- In-depth project plan.
- Risks.
- Systems Engineering plan.
- Summary.

GNAO/RTC Systems Engineering Objectives

- Apply best practices to GNAO/RTC.
- Ensure that as a system GNAO/RTC meets all the requirements derived from the GNAO/RTC science cases and requirements, and the Concept of Operations (ConOps).
- Ensure that the resulting top-level requirements are systematically decomposed to generate the system requirements specification.
- Define and control interfaces between subsystems within the system and between the system and the outside world.
- Define the most effective cost/schedule design solution that allows its implementation and integration for a smooth acceptance test to transition to science operations.

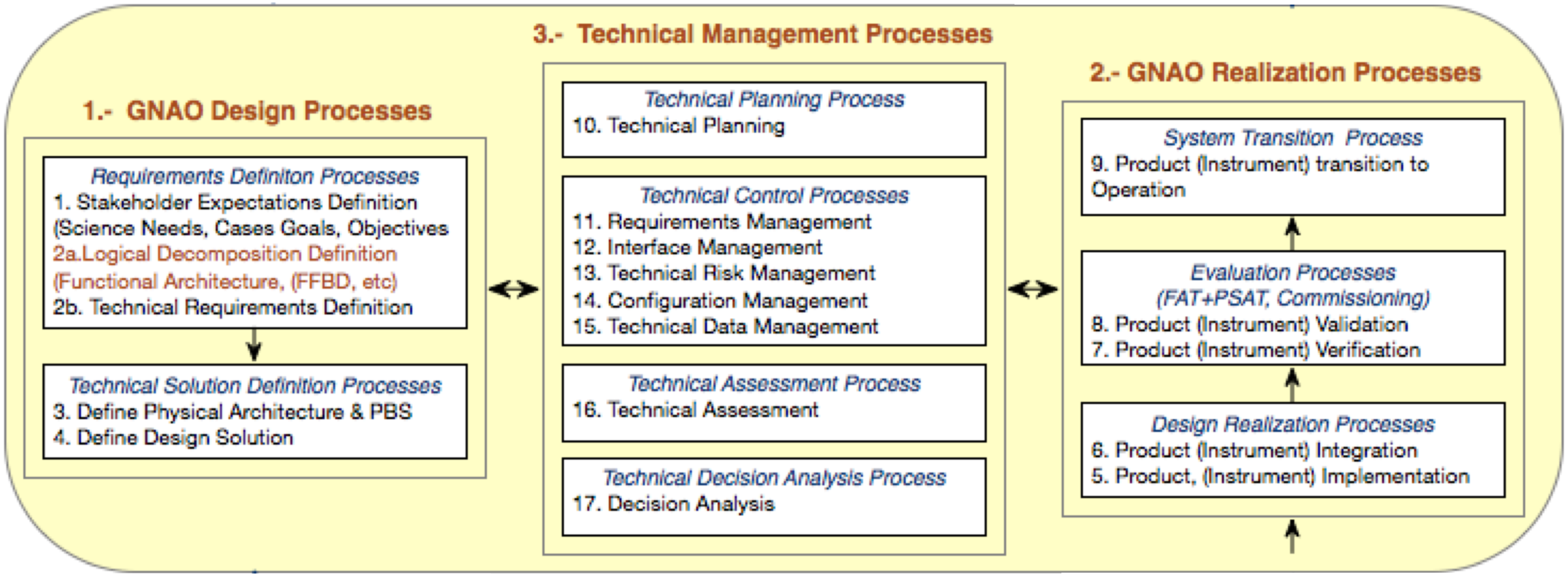
GNAO/RTC Systems Engineering Engine, 1 of 2

- The GNAO/RTC Project Team is adhering to a tailored Systems Engineering "Engine" (adapted from recommendations by NASA) to design and integrate the GNAO/RTC system.

- There are three sets of common technical processes in the context of the engine:
  1. System Design Processes,
  2. Product Realization Processes, and
  3. Technical Management Processes.

GNAO/RTC Systems Engineering Engine, 2 of 2

GNAO Systems Engineering Engine



***Product** in this context should also be considered*
*the **Instrument**, a **system or subsystem***

Dwgd by DSP Dec 2018, Adapted from NASA and INCOSE SE Handbooks for GNAO Project

Gemini Observatory — Exploring the Universe, Sharing its Wonders

National Science Foundation

GNAO/RTC Technical Management Processes

- The technical management processes are crosscutting tools for planning and executing the project.
- Systems Engineering will help coordinate the activities of these processes in conjunction with the integrated team, including the Principal Investigator, Project Manager, Subsystems Leads, and Scientists:
  - Technical Planning Process
  - Technical Control Processes
  - Requirements Management
  - Interface Management
  - Technical Risk Management
  - Configuration Management
  - Technical Data Management (Quality, Tech Tolerances and Budgets)
  - Technical Assessment (validation and verification)
  - Technical Decision Analysis Process (trade studies)
- Systems Engineering will assure that everyone on the project follows best Systems Engineering practices.

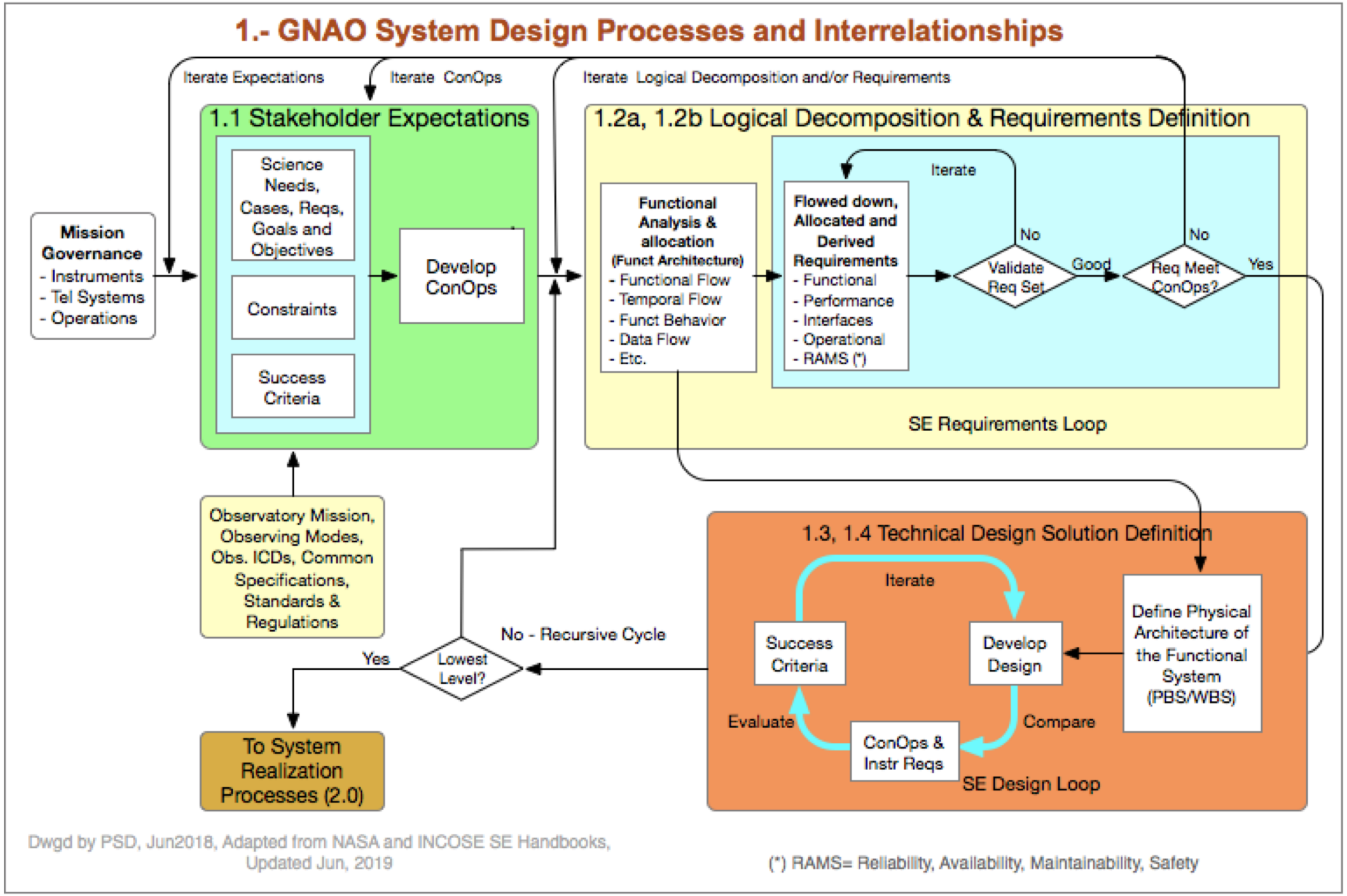
GNAO/RTC System Design Processes and Interrelationships, 1 of 2

- The System Design Processes are a key set of activities when designing a scientific facility or instrument
  - It is very important during the formulation phase (the design phase) of a project to invest in efficient, tailored design processes such as those shown in the GNAO SE Engine.

- Requirement Definition Processes:
  1. Define the Stakeholder Expectations
     - The activities of this process are mostly science driven to define from the science needs and science cases the High-level Science Requirements, and the development of the Concept of Operation (ConOps) of GNAO.
  2. (2a) Perform initial logical decomposition to define GNAO Functional Architecture, then, (2b) to decompose (flow down, derive and allocate) the System Technical Requirements

- Technical Solution Definition Processes:
  1. Define the physical architecture of the instrument to decompose the Product Breakdown Structure (PBS).
  2. Define the most cost effective technical design solution that must meets the set of system requirements, and satisfies the baselined stakeholder expectation of GNAO

GNAO/RTC System Design Processes and Interrelationships, 2 of 2



Topics

- Introduction.
- Brief technical description for context.
- In-depth project plan.
- Risks.
- Systems Engineering plan.
- Summary.

GNAO/RTC Summary

We have:

- Made significant technical progress.
- Identified and added the staff needed to manage and perform the GNAO/RTC project.
- Constructed a credible, fully-resourced project plan.
- Raised the project to very high priority in the observatory.

We believe that we have demonstrated that we have what it takes to successfully execute the GNAO/RTC project, on-time and on-budget, delivering a world-class Adaptive Optics facility to Gemini North!

GeMS at Gemini South

Topics

- Additional

Key Team Bios, 1 of 4

David Palmer, Project Manager

Dave Palmer has approximately 25 years of project and people management experience. He has successfully managed projects of varying sizes, up to about the $10M per year level, in both the public and private sectors. One of those projects was the Gemini Planet Imager (GPI), giving him invaluable experience and insights for the management of GNAO/RTC. On GPI (and other AO systems) he also had technical responsibility for the design and development of the Adaptive Optics Computer (AOC). He is a Computer Scientist by degree, specializing in real-time control for many of the past 39 years.

Gaetano Sivo, Principal Investigator

Gaetano Sivo has a Ph.D. in adaptive optics and astronomy. He has 10 years of experience working on adaptive optics for astronomy and instrumentation development of various systems. One of these was the Canary wide-field AO demonstrator in which Gaetano has participated in the design and conducted successfully the first on-sky demonstration of using new smart AO controllers on multi-laser AO systems. The past 5 years he has been dedicating his time on the Gemini South multi conjugated AO GeMS serving as instrument scientist and project scientist of various upgrades on this system such as the new Toptica laser.

Key Team Bios, 2 of 4

Natalie Provost, Lead Systems Engineer

Natalie is the Gemini South Lead Systems Engineer, where she has been working on AO projects since arriving in August 2018. Prior to that, she has had 18 years of aerospace and systems engineering experience on satellite systems. She joined Gemini from The Aerospace Corporation, where she was a key member of the commissioning team of the Joint Polar Satellite System (JPSS) at NASA; her role was as the Instrument Post Launch Test Lead and Instrument Systems Engineer for Flight Operations. Prior to that Natalie had significant System Engineering and Project Engineering positions at Northrop Grumman Aerospace Systems and Boeing Integrated Defense Systems.

Julia Scharwächter, GNAO Project Scientist

Julia Scharwächter has 14 years of work experience in observational astronomy, including 7 years at international observatories. Her main research interests include active galactic nuclei and the evolution of galaxies and their supermassive black holes with a focus on adaptive-optics-assisted observations and integral field spectroscopy. She holds a Ph.D. in astrophysics from the University of Cologne (Germany, 2005) and worked as an ESO Fellow at the European Southern Observatory in Chile and as a postdoctoral researcher at the Australian National University and at Paris Observatory in France. Julia joined Gemini Observatory as an Associate Scientist in 2016, where she has been the GMOS-N Instrument Scientist since July 2016 and the GNAO Project Scientist since April 2019.

Key Team Bios, 3 of 4

Paul Hirst, RTC Project Scientist

Paul Hirst has a Ph.D. in astronomy and 20 years of experience of operations, infra-red instrumentation, data reduction pipelines, and data archiving at major astronomical observatories. As head of the Technology Development Department at Gemini, Paul contributes expertise from both the technological and the research astronomer viewpoint to leverage new and established software and hardware technologies to efficiently meet the challenges of modern observatory operations and development.

Eduardo Marin, Project Engineer, LGS WP Lead

Eduardo Marin has approximately 12 years of experience working at astronomical observatories. He is an expert in nighttime operations focusing on the "Big-Picture" of how systems are interconnected and work together. Since 2011 he has been part of the GeMS team at Gemini South specializing in maximizing the efficacy of laser-assisted AO operations. He was a key member of the LGSF upgrades at both Gemini South and North, working on the integration and leading the night time commissioning of the new laser systems. He has an undergraduate degree in Astronomy and is currently pursuing a master's degree in Optical Sciences.

Key Team Bios, 4 of 4

William Rambold, Systems/Software Engineer

William Rambold has more than 35 years experience in the development and operational support of Astronomical Instruments at HAA, Gemini, CFHT, and as a private contractor. His areas of expertise include control systems, real-time software, electronics, detectors, systems engineering, project management, and system testing/verification. William has had significant involvement in many workhorse facility instruments, for example, developing the control system architecture for the Gemini GMOS spectrograph and providing project/systems engineering oversight for the CFHT MegaCam wide-field imager. He has been involved with AO related projects since the late 1980s; he developed the control system, and was project engineer, for the ASP Muhlmann Prize-winning CFHT HRCam image stabilizer; developed the software architecture for the ALTAIR AO system; and was responsible for operational support of the GeMS AO System Real-Time Controller