6.0 Management Plan, Schedule and Budget

6.1 Project Organization: The PI of MagAO-X is Dr. Jared Males, Steward Observatory Assistant Astronomer. The PI will direct the project in coordination with the Project Manager (PM) for MagAO-X. The PI will derive the system-level requirements and will confirm that the technical definitions for the project are sufficient to achieve the scientific goals for MagAO-X. The PM will work in conjunction with Team Leads to establish the requirements and technical specifications corresponding to the top-level scientific requirements. Each Team Leader will be responsible for a respective sub system and the execution of tasks to meet the milestones associated with the subsystem. Specific personnel at UA with the experience and skills required for this project have been identified and are included in the budget and schedule. Coordination between individual engineering teams will be the PM's responsibility along with the schedule, budget, external reporting to NSF, quality assurance, and configuration control. The MagAO-X project organization is shown in Fig. 6.1.

6.2 Project Management: The PM will assign tasks to Team leads, oversee the subcontract, and coordinate delivery, tests, and shipping. Weekly meetings will be held as necessary with all relevant personnel. Scheduling of installation, off-line testing, and on-sky testing will be under the direction of the PI. The project has been organized into a design phase and three subsequent development phases, and a WBS developed to organize the work and to assess progress. A high level summary of the project WBS and schedule is shown in Fig. 6.2 and detailed a WBS is shown in section 6.5.

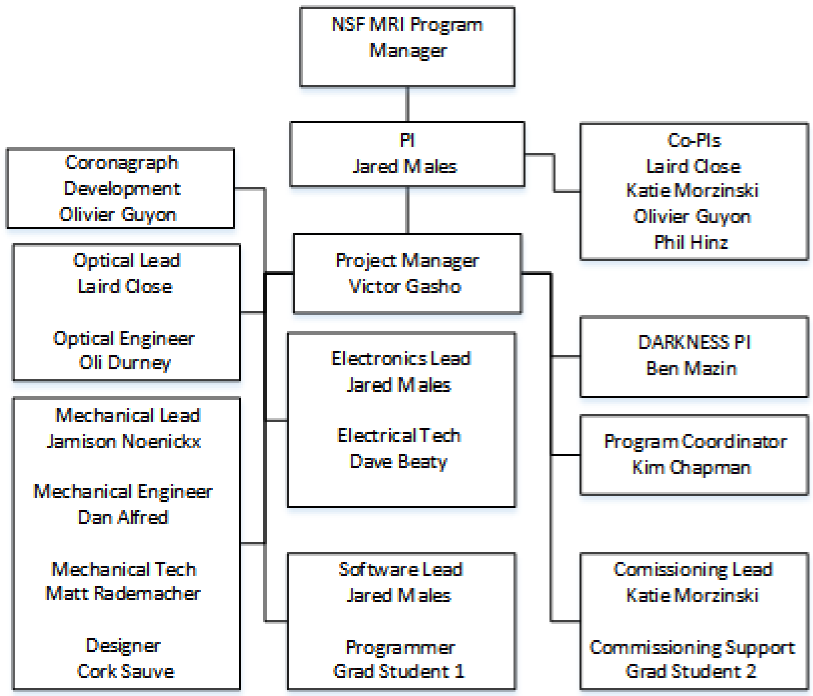


Figure 6.1: MagAO-X Project Organization

***Conceptual Design*:** This proposal is based on the MagAO-X conceptual design. A conceptual design review (CoDR) was held during the AO4ELT conference at Lake Arrowhead, CA, in Oct 2015 with a panel of three highly qualified external reviewers. After completing several actions to address concerns, the CoDR was passed.

***Design Phase*:** The preliminary design process will commence immediately following the MRI award. Here we will layout and model the system and create the various interfaces to the telescope and existing MagAO system. An outside panel of reviewers are being convened for the PDR to be held on 02 May 2017. Post PDR, the project will move on to the final design process that will address the issues identified at the PDR stage. The layout will be finalized and we will create fabrication drawings for mounts and interfaces. This process culminates with the internal final design review (FDR) targeted for June 14, 2017. Deliverables for the design phase include the PDR/FDR reports published on our website and at least one SPIE paper describing the design of the instrument.

After passing design reviews, component procurement will continue (long lead items such as the BMC

DM have already been procured), instrument construction, laboratory testing, and on-sky testing, will proceed and will be organized in three phases. We have budgeted for shipping the needed components between LCO and UA between telescope runs to continue development and testing. ***Phase I: Development of visible vAPP and LOWFS.*** Components will be populated on the floating bench, aligned, tested and then shipped to LCO for integration and one, three-day commissioning run. ***Pre-ship Review (PSR)*****:** Prior to shipping Phase I, we will provide an end-to-end demonstration of the instrument working in the lab to a panel of external experts, a Magellan Observatory requirement. Estimated deliverables for this phase include at least one SPIE paper documenting performance of the instrument and at least two refereed science papers utilizing the instrument.

Phase II: Development of visible Ex-AO. Phase II begins after Phase I testing, which allows parallel work in the lab on various improvements to the instrument to be developed for Phase II while phase I work is still ongoing. This enables the lab table to become a staging area for components to be tested and then implemented for the following stage of work. Phase II work integrates and aligns the PyWFS and science camera on the floating bench. After testing, the system will be shipped to LCO for integration and two, three-day commissioning runs spaced three months apart to address any issues. Estimated deliverables: at least one SPIE paper documenting performance of the instrument and at least two refereed science papers utilizing the instrument.

Phase III: Development of visible PIAACMC. Phase III will commence after Phase II commissioning run #1. The Lyot-based LOWFS and PIAACMC will be installed, aligned, and tested. The complete system will undergo final acceptance testing, then be shipped for re-installation at the LCO site. DARKNESS will be shipped to LCO. MagAO-X will be commissioned in two, three-day runs with a four-month spacing between them to resolve issues. Estimated deliverables of this phase include: at least one SPIE paper documenting performance of the instrument, a refereed paper (PASP) documenting system performance, and at least two refereed science papers utilizing the instrument.

DARKNESS Subaward**:** Funds for a subaward to collaborator Prof. Ben Mazin at UCSB was secured to support bringing the DARKNESS spectrograph to MagAO-X. Specifically, these funds will support a graduate student at UCSB who will coordinate interfacing DARKNESS to MagAO-X, develop FPWFS speckle control techniques, and perform post-processing of data under the direction of Prof. Mazin.

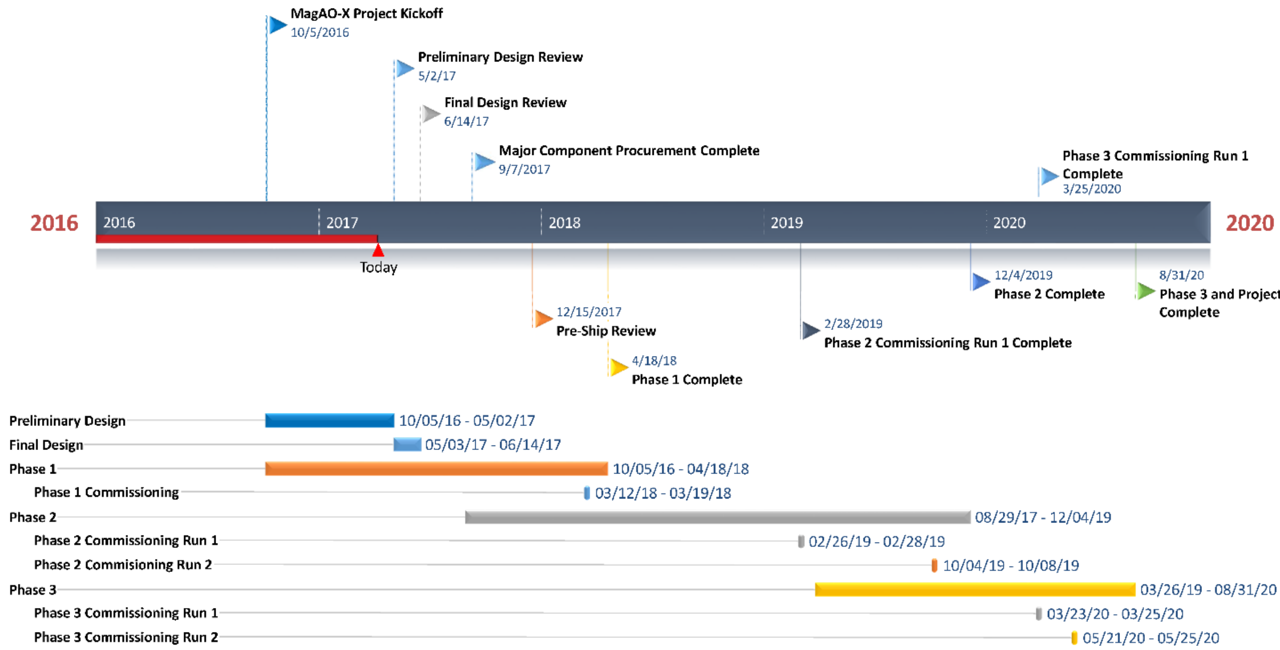


Figure 6.2: MagAO-X Project rolled-up work breakdown structure (WBS) and schedule

6.3 Risk Assessment: We have carefully structured the project plan and schedule to manage the risk associated with our aggressive goals. Our three-phased approach will allow us to develop, test, and deploy the instrument in manageable modules progressing from very low-risk in Phase I, to moderate-risk in Phase III. At each step, we have ensured the evolving instrument will be capable of producing ground breaking science. This phased approach allows a natural capability to de-scope the project if a technical or scheduling challenge prevents 100% completion, while still producing a scientifically capable instrument. Table 6.1 lists our assessment of some of the important risks of this project and their mitigation.

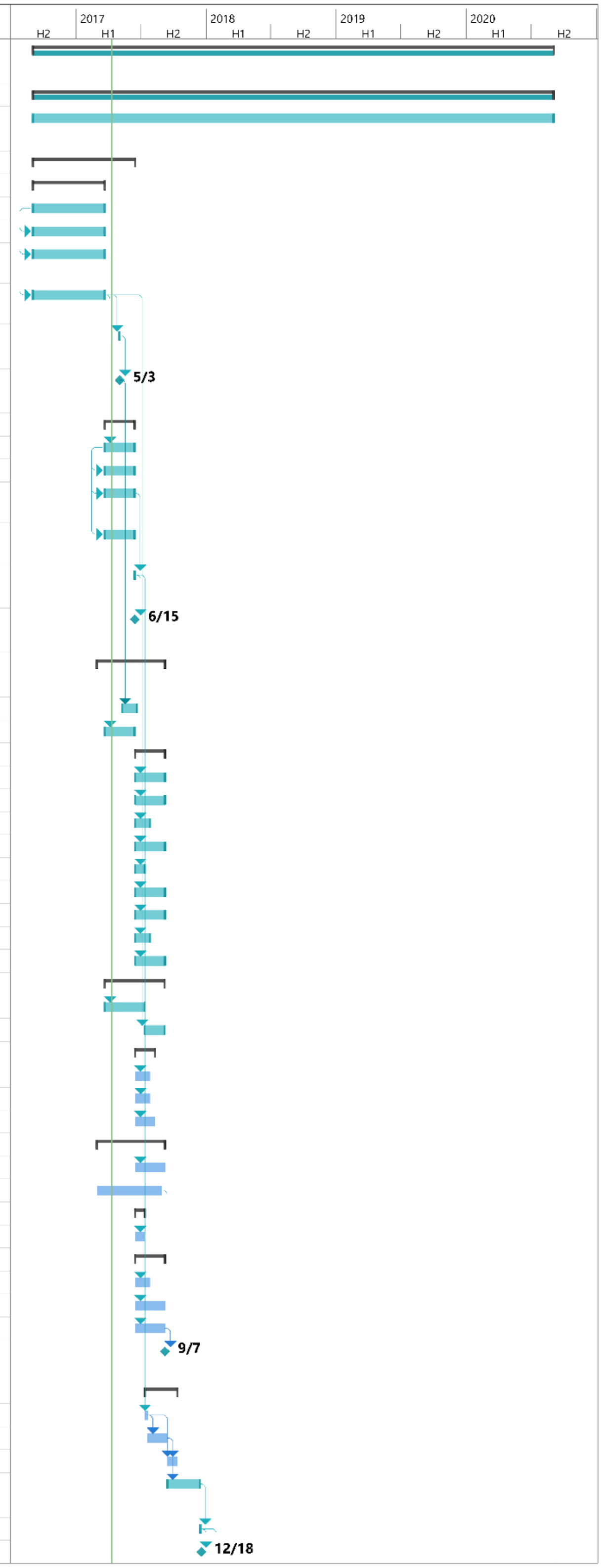
6.4 Design Availability: The MagAO-X instrument design will be made available through publications and through the project public website.

Table 6.1: Key Challenges and Risks

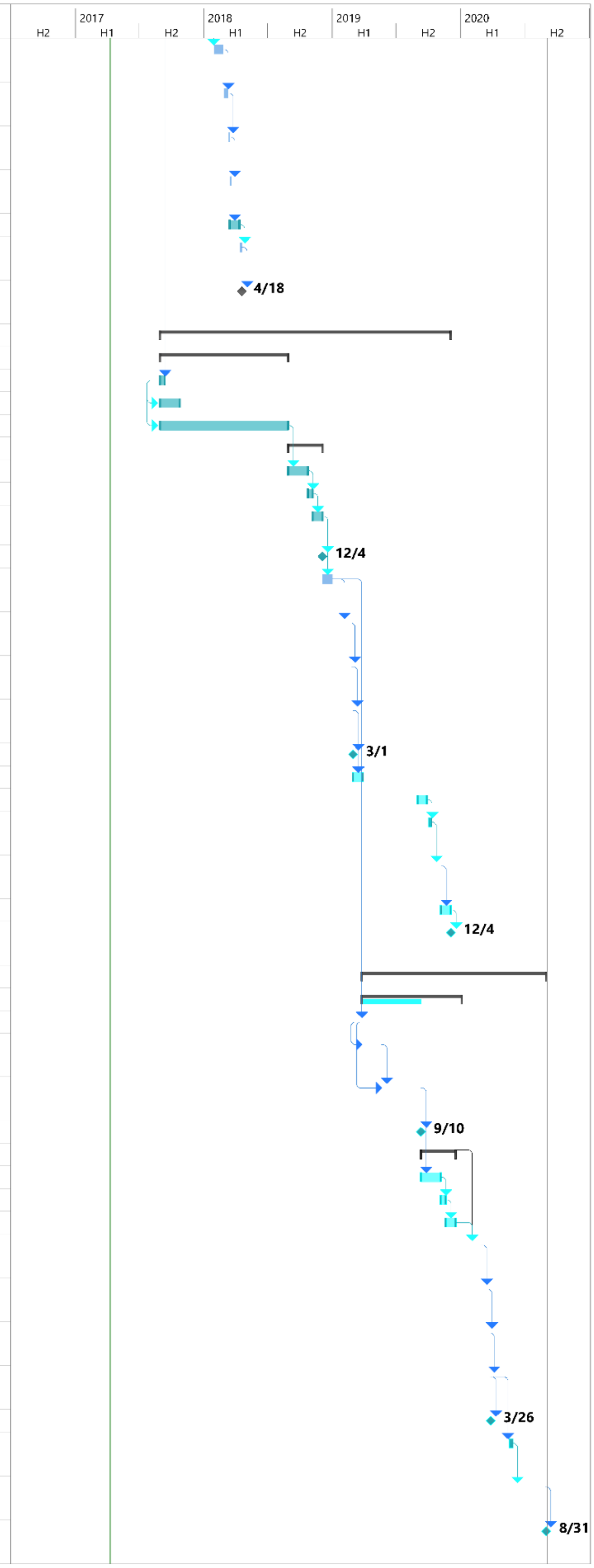
Risk	Likelihood / Severity	Comment/Mitigation
Existing MagAO doesn't work	very low / high	MagAO required for stroke requirement on MagAO-X DM. MagAO has <5% downtime to-date. Ability to use F/11 feed mitigates this risk
Unable to obtain telescope time for commissioning	very low / high	Commitment of time from the Director of Steward Observatory mitigates this risk.
Weather/seeing unsuitable for MagAO-X on commis- sioning runs	very low / low	Design based on median conditions. From extensive site char- acterization: very unlikely that a commissioning period is com- plete loss. Testing can be done in sub-standard conditions, mit- igating overall schedule risk.
Poor yield on DM (too many bad actuators)	low / moderate	We have budgeted for a 100% yield (inside illuminated pupil) with quote from BMC. A small number (1–2) of bad actuators can be masked.
Unable to obtain Pyramid of sufficient quality.	very low / high	Pyramid of visible-AO quality (<5 micron tip) already in pos- session (it is a spare component from MagAO construction) and tested successfully on-sky.
Unable to meet servo-loop time delay requirement.	low / moderate	Re-use of SCExAO software, with upgraded COTS GPUs means that we have a on-sky tested solution.
PIAACMC does not perform as designed	moderate / low	Affects only most aggressive 1 λ/D science cases. Significant science still achieved with on-sky proven vAPP coronagraph at $> 2\lambda/D$. Optical design easily accommodates alternatives, such as vector vortex, apodized Lyot.
Unable to obtain optical quality spec. on OAP relays	low / low	Two experienced OAP vendors will meet our spec. Our low, mid, and high freq. specs will produce $\sim$ 12 nm rms (even before DM correction) see Table 1.
Unable to meet NCP aberra- tion specifications	low / low	The LOWFS is common path after the Lyot stop: *all* low orders (LO) will be sensed and removed at DM. HO NCP will be <30 nm rms using 4D interferometer for acceptance & alignment.
Unable to control vibrations on MagAO-X bench	low / moderate	Vibration environment well understood from MagAO. Most se- vere for PIAACMC near $1\lambda/D$. vAPP coronagraph essentially impervious to vibrations (pupil-plane optic).
Coronagraphic LOWFS does not work.	low / moderate	The LOWFS technique has been demonstrated on-sky at SCExAO (Singh et al., 2015).
Focal plane WFS speckle control does not perform well enough.	moderate / low	Speckle nulling demonstrated on-sky (Martinache et al., 2014). Most science possible without FPWFS, i.e., raw PSF contrast is sufficient combined with SDI and ADI techniques.

6.5 Detailed Schedule and WBS

ID	Task Name	Duration	Start	Finish
1	**Mag-AO X**	**1044 days**	**9/1/16**	**9/2/20**
2	**Project Personnel**	**1043 days**	**9/1/16**	**8/31/20**
14	Travel	52.15 mons	9/1/16	8/31/20
15	**Design**	**205 days?**	**9/1/16**	**6/15/17**
16	**Preliminary Design**	**144 days**	**9/1/16**	**3/21/17**
17	Optical Design	7.2 mons	9/1/16	3/21/17
18	Optical Mount Design	7.2 mons	9/1/16	3/21/17
19	Electronics and Controller Design	7.2 mons	9/1/16	3/21/17
20	RT Software Development	7.2 mons	9/1/16	3/21/17
21	Preliminary Design Review	1 day	5/2/17	5/2/17
22	Preliminary Design Complete	0 days	5/3/17	5/3/17
23	**Final Design**	**60 days**	**3/22/17**	**6/13/17**
24	Optical Design	3 mons	3/22/17	6/13/17
25	Optical Mount Design	3 mons	3/22/17	6/13/17
26	Electronics and Controller Design	3 mons	3/22/17	6/13/17
27	RT Software Development	3 mons	3/22/17	6/13/17
28	Final Design Review	1 day?	6/14/17	6/14/17
29	Final Design Complete	0 days	6/15/17	6/15/17
30	**Component Procurement**	**137 days**	**2/28/17**	**9/7/17**
31	Optics Table (Cost Share)	6 wks	5/10/17	6/20/17
32	Interferometer Zygo (Cost Share)	12 wks	3/22/17	6/13/17
33	**Optics**	**60 days**	**6/15/17**	**9/6/17**
34	OAP12-05.0-02Q, AlSiO (4ea.)	12 wks	6/15/17	9/6/17
35	OAP12-05.0-02Q, Protected Ag (4 ea.)	12 wks	6/15/17	9/6/17
36	Flats (14ea.)	6 wks	6/15/17	7/26/17
37	PIAA (2 sets)	12 wks	6/15/17	9/6/17
38	Shear Plate/Custom Alignment Tools	4 wks	6/15/17	7/12/17
39	Etched Lyot and Pupil Masks	12 wks	6/15/17	9/6/17
40	APP Coronagraph	12 wks	6/15/17	9/6/17
41	Miscellaneous Small Optics/Lenses (Cost Sh	6 wks	6/15/17	7/26/17
42	Focal Plane Mask	12 wks	6/15/17	9/6/17
43	**Cameras**	**120 days**	**3/22/17**	**9/5/17**
44	OCAM 2K (Cost Share)	16 wks	3/22/17	7/11/17
45	IXON 888 (2ea.)	8 wks	7/12/17	9/5/17
46	**Mounts**	**40 days**	**6/15/17**	**8/9/17**
47	MMOA-2 (8 ea.)	6 wks	6/15/17	7/26/17
48	Flat Mounts K series 11 ea.	6 wks	6/15/17	7/26/17
49	K Mirror Rotator	8 wks	6/15/17	8/9/17
50	**Positioners**	**137 days**	**2/28/17**	**9/6/17**
51	PI 331 (1 ea.)	12 wks	6/15/17	9/6/17
52	DM1	26 wks	2/28/17	8/28/17
53	**Computer**	**20 days**	**6/15/17**	**7/12/17**
54	Dell (3 ea.)	4 wks	6/15/17	7/12/17
55	**Telescope Simulator**	**60 days**	**6/15/17**	**9/6/17**
56	Artificial Source	6 wks	6/15/17	7/26/17
57	Atmospheric Phase Mask	12 wks	6/15/17	9/6/17
58	Fabricated Items	12 wks	6/15/17	9/6/17
59	Major Components Procurement Complete	0 days	9/7/17	9/7/17
60	**Assembly**	**65 days**	**7/13/17**	**10/11/17**
61	Populate Optics on Table	1 wk	7/13/17	7/19/17
62	Software Development	2 mons	7/20/17	9/13/17
63	Alignment	4 wks	9/14/17	10/11/17
64	Testing	13 wks	9/14/17	12/13/17
65	Pre-Ship Review	2 days	12/14/17	12/15/17
66	Pre-Ship Review Complete	0 days	12/18/17	12/18/17



ID	Task Name	Duration	Start	Finish
67	Shipping	1 mon	1/29/18	2/23/18
68	Integrate at Telescope	2 wks	2/26/18	3/9/18
69	System Checkout on Telescope	3 days	3/12/18	3/14/18
70	Commissioning	3 days	3/15/18	3/19/18
71	Return Shipment	1 mon	3/15/18	4/11/18
72	Contingency	1 wk	4/12/18	4/18/18
73	**Phase 1 Complete**	0 days	4/18/18	4/18/18
74	**Phase 2**	**591 days**	**8/29/17**	**12/4/19**
75	**Assembly**	**260 days**	**8/29/17**	**8/27/18**
76	Populate Optics on Floating Bench	2 wks	8/29/17	9/11/17
77	Alignment	2 mons	8/29/17	10/23/17
78	Software Development	13 mons	8/29/17	8/27/18
79	**Testing**	**70 days**	**8/28/18**	**12/4/18**
80	End to End Tests	2 mons	8/28/18	10/22/18
81	Final Acceptance Tests	2 wks	10/23/18	11/5/18
82	Package and Ship System	1 mon	11/6/18	12/3/18
83	Phase 2 Testing Complete	0 days	12/4/18	12/4/18
84	Shipping	1 mon	12/4/18	12/31/18
85	Integrate at Telescope	2 wks	2/5/19	2/18/19
86	System Checkout on Telescope	1 wk	2/19/19	2/25/19
87	Commissioning Run 1	3 days	2/26/19	2/28/19
88	Commisioning Run 1 Complete	0 days	3/1/19	3/1/19
89	Return Shipment	1 mon	3/1/19	3/28/19
90	Shipping to Telescope	1 mon	9/1/19	9/26/19
91	Commissioning Run 2	3 days	10/4/19	10/8/19
92	Contingency	1 mon	10/9/19	11/5/19
93	Return Shipment	1 mon	11/6/19	12/3/19
94	**Phase 2 Complete**	0 days	12/4/19	12/4/19
95	**Phase 3**	**374 days**	**3/26/19**	**8/31/20**
96	**Assembly**	**204 days**	**3/26/19**	**1/3/20**
97	Populate Optics on Floating Bench	2 mons	3/26/19	5/20/19
98	Alignment	2 mons	3/26/19	5/20/19
99	Software Development	4 mons	5/21/19	9/9/19
100	Software Development Complete	0 days	9/10/19	9/10/19
101	**Testing**	**70 days**	**9/10/19**	**12/16/19**
102	End to End Tests	2 mons	9/10/19	11/4/19
103	Final Acceptance Tests	2 wks	11/5/19	11/18/19
104	Package and Ship System	1 mon	11/19/19	12/16/19
105	Shipping	1 mon	2/3/20	2/28/20
106	Integrate at Telescope	2 wks	3/2/20	3/13/20
107	System Checkout on Telescope	1 wk	3/16/20	3/20/20
108	Commissioning Run 1	3 days	3/23/20	3/25/20
109	Commmissioning Run 1 Complete	0 days	3/26/20	3/26/20
110	Commissioning Run 2	3 days	5/21/20	5/25/20
111	Contingency	69 days	5/26/20	8/28/20
112	**Phase 3 Complete**	0 days	8/31/20	8/31/20



6.6 Budget

The total project cost is $3.280M. The total cost includes $2.296M of direct costs from NSF and $984K of cost share from non-federal sources. The estimate included all labor costs, operations, capital expenses, travel, and indirect (F&A) charges. We have revised these cost based on developments during the preliminary design phase. Fig. 6.3 contains the current "MagAO-X Burn Chart", showing the total costs for the project, current actual expenditures (as of March 31, 2017), planned cost share and planned direct costs over time.

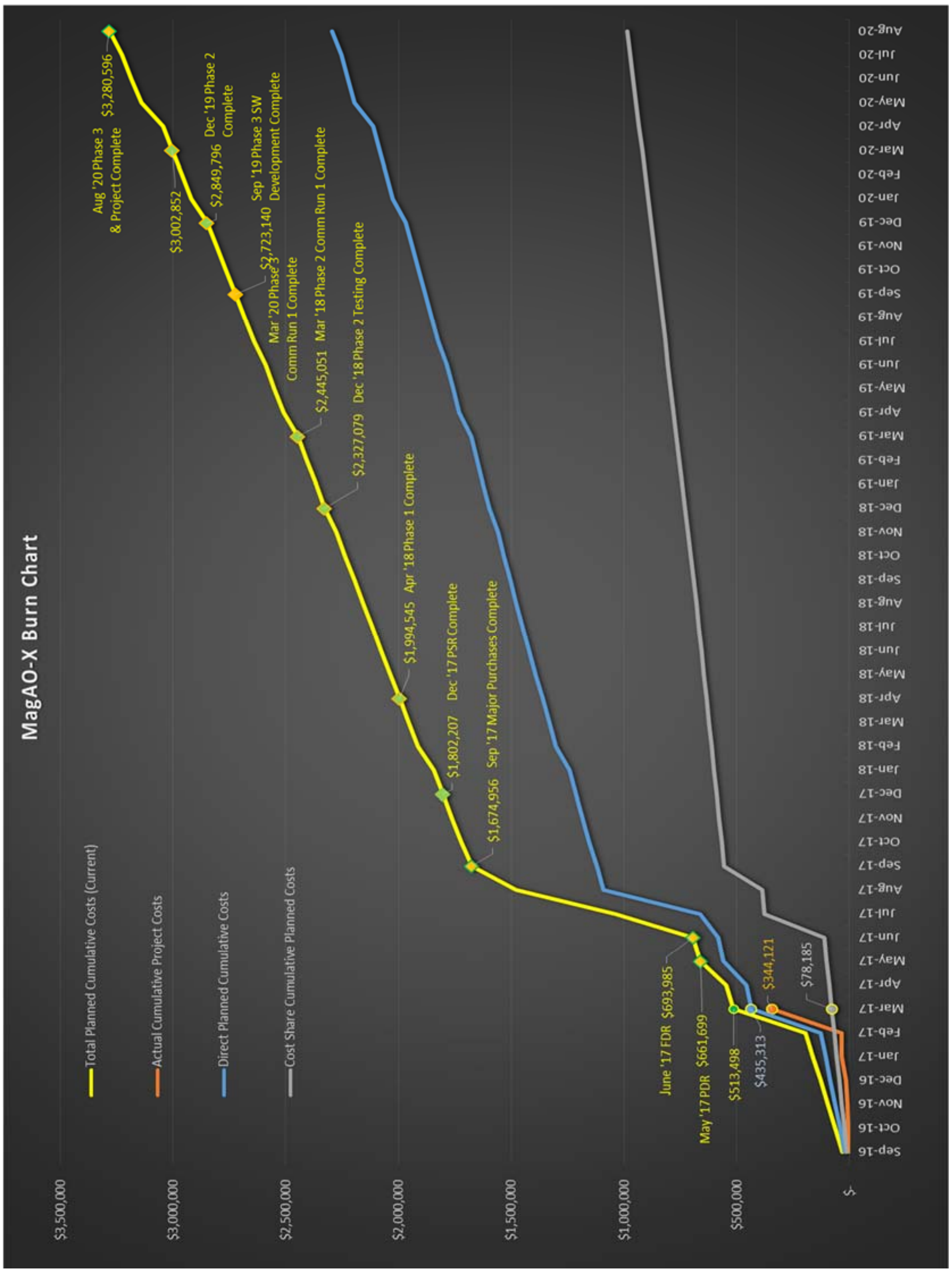


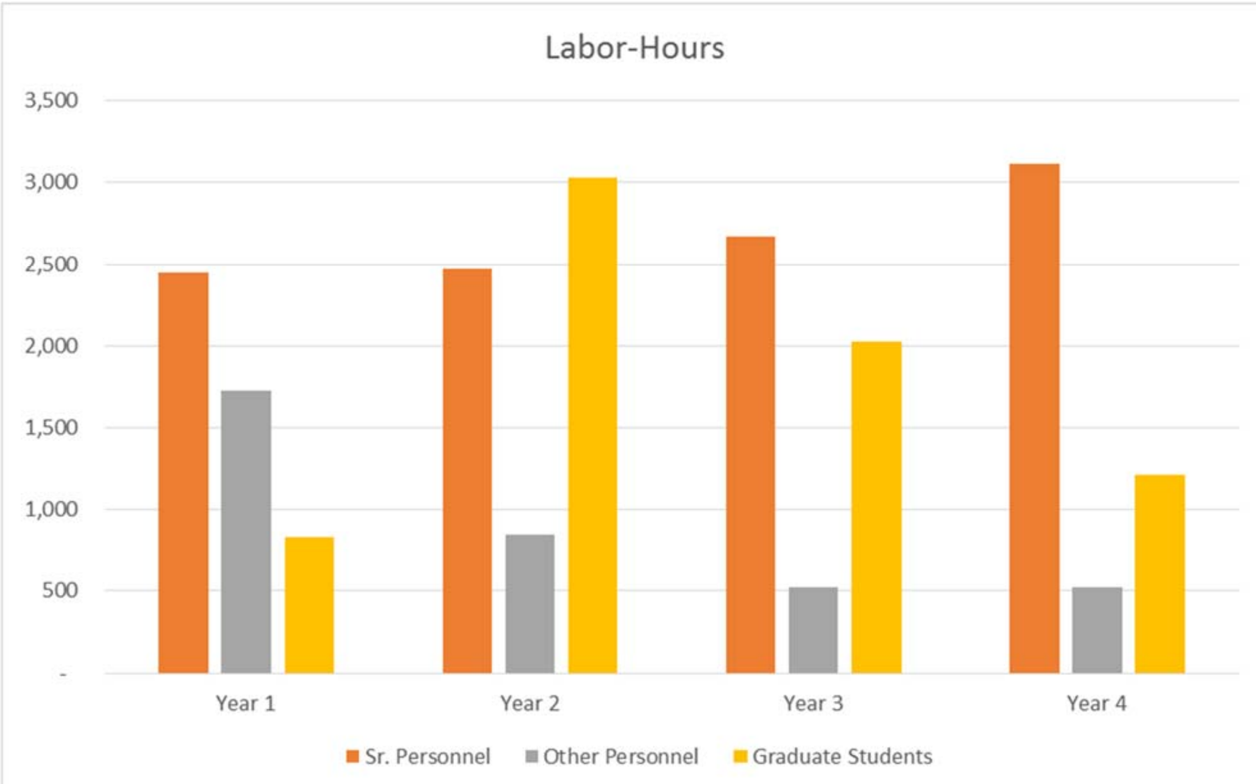
Figure 6.3: MagAO-X Burn

6.6.1 Labor and Personnel

Table 6.2 contains the project personnel and description of their assigned tasks and/or past experience. Figure 6.3 shows how the labor hours and labor costs are distributed over time. The labor hours for senior personnel slowly ramp up as the project progresses. This is mainly due to more expertise needed during phase two and three commissioning occurring in years 3 and 4. The other personnel such as the engineers and technicians are primarily required in year 1 and tapering off in year 2. The relatively low hours for the engineers and technicians is due to the experimental nature of the project using off the shelf equipment that requires very little custom designs and fabrication. Graduate student help ramps up in year 2 as the instrument readies for commissioning in phase 1 and tapers off in years 3 and 4 as more senior personnel take on more of the commissioning tasks.

Table 6.2: Project personnel.

Project Title	Name	Project Role
Sr. Personnel		
Pricipal Investigator	Dr. Jared Males	Will oversee the technical direction of the entire project and will lead the software and electronics group.
Co-PI	Dr. Laird Close	Dr. Close is the overall MagAO system PI and optics team lead.
Co-PI	Dr. Phil Hinz	Dr. Hinz is the PI of the CLIO Infrared Camera.
Co-PI	Dr. Olivier Guyon	Dr. Guyon is the world leader in coronagraph design.
Co-PI	Dr. Katie Morzinski	Dr. Morzinski has many years of experience in AO science, which will be valuable for the instrument testing and commissioning.
Other Personnel		
Project Manager	Mr. Victor Gasho	Mr. Gasho has managed several complex telescope instrument/system builds including Mag-AO He will be responsible for project cost, schedule, configuration management and task assignment.
Optical Engineer	Mr. Oli Durney	Mr. Durney was the principal optical engineer tor LBTI and has designed the optics for MagAO-X
Mechanical Engineer	Mr. Jamison Noenickx	Mr. Noenickx was involved with the MagAO development. Mechanical team lead.
Mechanical Engineer	Mr. Daniel Alfred	Mr. Alfred is in charge of the thermal analysis of the electronics rack and table environment. He was formerly on the Osiris-Rex project in that role.
Designer	Mr. Cork Sauve	Mr. Fern will be responsible for the engineering/shop drawings for the system under the direction of Mr. Noenickx.
Electrical Technician	Mr. Dave Beaty	Mr. Beaty will be responsible for the electrical interconnects for the system under the direction of Dr. Males.
Mechnical Technician	Mr. Matt Rademacher	Mr. Rademacher will be responsible for mechanical assembly of the system under the direction of Mr. Noenickx.
Program Coordinator	Ms. Kim Chapman	Ms. Chapman will be responsible for arranging travel, tracking account expenditures, effort reporting, and purchasing.
Students		
Graduate Student 1	Ms. Kelsey Miller	Ms. Miller will assist in the design, build and phase 1-2 commissioning of the instrument.
Graduate Student 2	Ms. Lauren Schatz	Ms. Schatz will be tasked with the design, build and phase 1-2 commissioning of the instrument.
Graduate Student 3	Mr. Joseph Long	Mr. Long will assist with phase 2 - 3 build and commissioning.



	Item	Year 1		Year 2		Year 3		Year 4		Total	
		Labor Cost	Labor Hours	Labor Cost	Labor Hours	Labor Cost	Labor Hours	Labor Cost	Labor Hours	Labor Cost	Labor Hours
1	Sr. Personnel	$ 136,653	2,448	$ 140,422	2,468	$ 155,508	2,669	$ 192,464	$ 3,118	$ 625,047	$ 10,703
2	Other Personnel	$ 58,556	1,726	$ 22,231	842	$ 13,341	522	$ 13,741	$ 522	$ 107,869	$ 3,612
3	Graduate Students	$ 24,095	828	$ 76,052	3,028	$ 54,347	2,028	$ 32,930	$ 1,214	$ 187,423	$ 7,098
4	Fringe Benefits	$ 71,477		$ 67,337		$ 66,483		$ 76,543		$ 281,840	$ -
	Total	**$ 290,782**	**5,002**	**$ 306,042**	**6,338**	**$ 289,678**	**5,219**	**$ 315,678**	**4,854**	**$ 1,202,180**	**21,413**

Figure 6.3: Project personnel labor hours and costs over time.

6.7 Equipment, Shipping, Subcontracts, Travel and Indirect

Table 6.3 contains the rollup costs for the equipment, shipping and travel costs. Table 6.4 shows the current rolled-up costs for major capital equipment and quotes for purchased items (some purchased items are estimated costs were quotes were not available or where called out as miscellaneous items). Please note that the capital equipment quotes are confidential and can be provided upon request. The air-freight and ground shipping is based on fresh quotes from WJ Byrnes and Co. for the Tucson to Santiago leg and actuals from the FIRE instrument shipping for the Santiago to LCO leg. A quote for the return shipments of the table and electronics rack crates were also received from W.J. Byrnes. There will be five round-trip shipments of the table and electronics rack, with the final shipment being a one-way to the site for commissioning run 2 in phase 3. The table legs and shipping fixture will be shipped one time, one-way to the site in phase 1. A subcontract will be let to University of California Santa Barbara (UCSB) to provide the DARKNESS instrument to be used on the MagAO-X system. The funds will be used to support a graduate student at UCSB under the supervision of PI Dr. Ben Mazin. Travel costs are based on previous travel for the Mag-AO runs and includes air fare from Tucson to La Serena and lodging at LCO. Indirect costs are charged on labor, non-capital equipment, travel, shipping and on the first $25K of subcontracts at the rate of 53.5%. The total indirect cost of the project are $495K (Note that the cost share portion of the project do not incur indirect charges).

Table 6.3: Rolled-up costs for the equipment, travel, shipping and subcontracts.

		Year 1	Year 2	Year 3	Year 4	Total
1	Equipment	$ 476,872	$ 1,751	$ 1,804	$ 1,858	$ 482,284
2	Travel	$ -	$ 24,637	$ 25,376	$ 52,274	$ 102,287
3	Shipping	$ 12,740	$ 12,600	$ 25,200	$ 39,000	$ 89,540
4	Subcontracts	$ -	$ -	$ 23,650	$ 24,286	$ 47,936
	Total	**$ 489,612**	**$ 38,988**	**$ 76,030**	**$ 117,418**	**$ 722,047**

Table 6.4: Equipment costs. Capital equipment quotes are confidential and can be provided upon request.

Capital Equipment					
	Qty	**Item**	**Unit Price**	**Total Cost**	**Vendor**
1	8 ea.	2" OAPs Hi-Precision Quality			AOS
2	1 ea.	APP Coronagraph			
3	1 ea.	Focal Plane Mask			
4	1 ea.	K Mirrors Rotator			
5	1 ea.	Deformable Mirror (DM1)			BMC
6	1 ea.	Artificial Source			Fianium
7	1 ea.	Stacis Optical Table			TMC
8	1 ea.	OCAM2K Camera			First Light
9	2 ea.	IXON 888 Camera			Andor
10	1 ea.	PI 330 Fast Tip-Tilt Stage			PI
11	2 ea.	Real Time Computer			Custom
12	1 ea.	PCIe Expansion			Custom
13	1 ea.	Instrument Control Computer			Custom
14	1 ea.	AO Operations Computer			Custom
			Total	**$ 1,109,718**	
Non-Capital Equipment					
15	14 ea.	Flats	$ 1,000	$ 14,000	Thorlabs
16	2 ea.	PIAA	$ 2,000	$ 4,000	
17	1 set	K Mirrors	$ 3,000	$ 3,000	Thorlabs
18	1 ea.	Atmospheric Phase Mask	$ 4,000	$ 4,000	
19	1 ea.	Shear Plate/Custom Alignment Too	$ 1,000	$ 1,000	
20	1 ea.	Etched Lyot and Pupil Masks	$ 1,000	$ 1,000	In-house
21	8 ea.	MMOA-2 Mount	$ 3,035	$ 24,280	AOS
22	8 ea.	Flat Mounts K series	$ 500	$ 4,000	Thorlabs
23	1 lot	Fabricated Items	$ 2,600	$ 2,600	In-house
24	1 lot	Miscellaneous Optics	$ 4,604	$ 4,604	Various
25	1 lot	Shipping Crates	$ 6,000	$ 6,000	Various
26	2 ea.	Transportable Storage 8 TB	$ 2,395	$ 4,790	Custom
27	2 ea.	UA Fixed Storage 136 TB	$ 20,000	$ 40,000	Custom
28	1 lot	Various Spares	$ 12,795	$ 12,795	Various
29	1 ea.	Diverging Lens for Interferometer	$ 3,003	$ 3,003	Zygo
			Total	**$ 129,071**	