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Partnering with Industry: Lessons Learned from the Wide Field Instrument on the Wide Field InfraRed Survey Telescope Mission

Hume L. Peabody[1]
NASA-GSFC, Greenbelt, MD 20771

and

Jeanette Domber[2]
Ball Aerospace, Boulder, CO 80301

Through most of the project formulation prior to Phase A, the Wide Field InfraRed Survey Telescope (WFIRST) project was developed as a Goddard Space Flight Center (GSFC) in house mission with one secondary instrument developed by JPL and an existing telescope donated from elsewhere in the federal government and managed by the original industry vendor. GSFC was responsible for the spacecraft bus, the instrument supporting structure and the Wide Field Instrument (WFI), which provides the primary science for the mission. Shortly before the beginning of Phase A, NASA codified its acquisition strategy for WFIRST to explore a more substantial role for industry in the mission. The project decided to have a large portion of the WFI be co-developed by industry. This paper describes lessons learned and recommendations for bringing potential industry partners into a project at later stages of conceptual design and presents viewpoints from both the vendor and customer on the experience with WFIRST.

Nomenclature

ACS	= *Attitude Control System*
AG	= *Auxiliary Guider*
APG	= *Annealed Pyrolytic Graphite*
CGI	= *CoronaGraph Instrument*
COBA	= *Cold Optics Baffle Assembly*
EW	= *Element Wheel*
FCR	= *Facility Cryogenic Radiator*
FPA	= *Focal Plane Assembly*
FPE	= *Focal Plane Electronics*
GSFC	= *Goddard Space Flight Center*
IC	= *Instrument Carrier*
IFC	= *Integral Field Channel*
IP	= *Intellectual Property*
JPL	= *Jet Propulsion Laboratory*
MCR	= *Mission Concept Review*
NASA	= *National Aeronautics and Space Administration*
OCI	= *Organizational Conflict of Interest*
RFP	= *Request for Proposal*
SCE	= *Sensor Control Electronics*
SRR	= *System Requirements Review*
TBA	= *Thermal Bus Assembly*
TOSA	= *Transmissive Optics Selection Assembly*
WFI	= *Wide Field Instrument*
WFIRST	= *Wide Field InfraRed Survey Telescope*

I. Introduction

THE Wide Field InfraRed Survey Telescope (WFIRST) mission was selected as the top-ranked large space mission in the 2010 New Worlds, New Horizons Astronomy and Astrophysics Decadal survey. WFIRST follows in the footsteps of the great Astrophysics Observatories including: the Hubble Space Telescope, Chandra, Spitzer, and the James Webb Space Telescope. WFIRST will study dark energy, exoplanets, and the near infrared sky and is conceived as a Class B, serviceable observatory, planned for launch in the mid-2020s with an orbit around the L2 Earth/Sun Lagrange point. A unique aspect of the mission is the use of an existing 2.4 m diameter telescope developed for another federal government agency and later transferred to the National Aeronautics and Space

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[1] Staff Thermal Engineer, Mail Stop 545, Goddard Space Flight Center, Greenbelt MD 20771.
[2] WFIRST WFI Deputy Program Manager, Ball Aerospace, 1600 Commerce St, Mail Stop RA-6, Boulder, CO 80301

Administration (NASA). The telescope provides the front end optics for a pair of instruments, which are supported by an Instrument Carrier (IC) for precise metering to the telescope. The first of these two instruments, the Wide Field Instrument (WFI) provides wide field imaging and slitless spectroscopic capabilities to probe dark energy, conduct a galactic planetary census, and provide a near-IR survey. The WFI utilizes a 3x6 array of H4RG detectors to provide a sky field of view over 100x larger than the Wide Field Camera 3 instrument on the Hubble Space Telescope. The second instrument, the CoronaGraph Instrument (CGI), is a technology demonstration used to directly image exoplanets and debris discs around nearby stars developed and provided by the Jet Propulsion Laboratory (JPL).

WFIRST completed its Mission Concept Review (MCR) in late 2015 and entered the mission formulation phase in February of 2016. Shortly before the MCR, direction was given to the project to provide a more substantial role for industry involvement. Prior to that point, the CGI was developed and managed by JPL but the rest of the mission was managed by the Goddard Space Flight Center (GSFC), including the design and development of the spacecraft bus, the WFI, and management of the industry vendor for the telescope. After internal discussions within the project, the decision was made to have industry develop a substantial portion of the WFI while GSFC would retain the spacecraft bus as well as the Focal Plane System for the WFI. A sequential, three part approach was utilized to acclimate potential industry partners to the WFIRST mission, and WFI design and requirements all while continuing in parallel on the normal product development cycle towards the System Requirements Review for WFI. This paper describes the approach taken to minimize the impact to schedule and to transfer GSFC knowledge as efficiently as possible to potential industry partners.

II. WFI Mission Concept Review Design

The WFI MCR[1] design featured a focal plane assembly (FPA) consisting of a 3x6 array of H4RG detectors mounted to a MOSAIC Plate structure. The FPA was cooled by a reverse Brayton cycle turbomachinery cryocooler to 100 K. Incoming light from the telescope was reflected off a flat fold mirror, to a powered mirror (M3 in Figure 1, making it the third of a three mirror anastigmatic design along with the primary and secondary mirrors in the telescope), through one of eight optical elements in an Element Wheel, then to an actuated, flat fold mirror, and lastly to the FPA. A Cold Optics Baffle Assembly (COBA) after the Element wheel (EW) reduces the risk of stray light on the FPA. Six of the eight elements in the Element Wheel were filters at various wavelengths, one is a blank, and the last was a Grism (Grating Prism), which separated the incoming light into respective spectra for one of the science surveys. One core functionality of the WFI is to provide data to the spacecraft Attitude Control System (ACS) for fine pointing based on centroiding around stars found in the output for each of the 18 H4RG detectors during imaging mode. However, when the WFI is in spectroscopy mode and the Grism is in the beam position, the images available from the detectors were not considered to be of sufficient quality to provide the necessary data to the ACS for fine guiding. Therefore, a reflective optical element was added to the front of the grism, with the reflected light directed to an Auxiliary Guider (AG) which would process the image from the

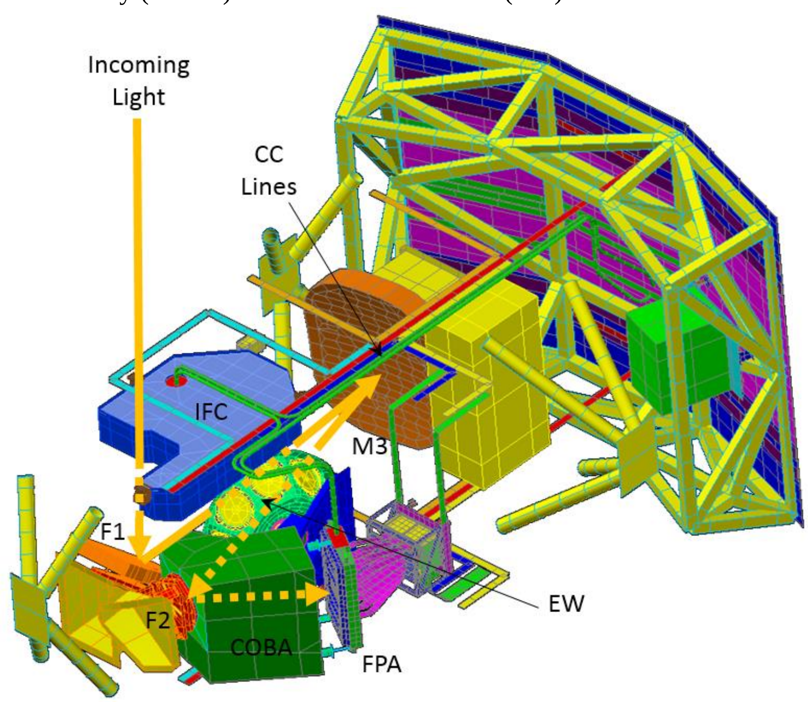

Figure 1. WFI MCR Design: WFI MCR Design: *Major internal components of the WFI include fold mirror 1 (F1), tertiary mirror (M3), element wheel (EW), actuated fold mirror 2 (F2), and the Focal Plane Array (FPA). The Cold Optics Baffle Assembly provides a cold scene for the detectors. A secondary Integrating Field Channel provides simultaneous spectroscopic measurements*

light and provide the necessary data for fine guiding while in spectroscopy mode. A secondary channel, the Integral Field Channel (IFC), included a complete parallel optical light path from the telescope and its own detector unit with a connection to the cryocooler to cool the IFC FPA for some of the mission's spectroscopic surveys.

All optics, focal planes, and the Relative Calibration system were mounted to a composite optical bench for stability. This bench was directly cooled to 170 K using ethane heatpipes to transport the bench heat to two dedicated passive radiators. A third radiator provided the cooling for the cryocooler and its associated electronics. The Focal Plane System included the Focal Plane Array with H4RG detectors at one end of a composite frame and the Sensor Control Electronics (SCE) at the other end so that the entire Focal Plane System could be tested and delivered as one unit. The MOSAIC plate, which supports the focal plane array, was directly cooled via a heat exchanger mounted to the plate and flowing gaseous neon from the cryocooler. The SCEs were cooled by a heat pipe connection to the top panel of the bench and a heat strap connection to the bottom bench panel. Both of these bench connections were closely located to a main header heat pipe to the bench radiators. The frame was kinematically mounted to the bench via 3 sets of bipods. The SCEs digitized each analog output signal from an H4RG and were located close to the sensors themselves to reduce the impact of noise on the signal. The digitized signals were then passed to each Sensor Control Unit cards, which were all located in a room temperature electronics box called the Focal Plane Electronics (FPE) which was mounted in one of the spacecraft bays below the cold portion of the instrument. Located with the FPE were the primary and redundant Instrument Control and Data Handling and Mechanism Control Electronics avionics boxes to complete the full WFI complement of hardware. The design is required to be serviceable, allowing the cold module to be replaced by a potential future replacement instrument as well as the avionics being on a serviceable panel for the spacecraft.

III. Introduction of WFI to Industry

During the Concept and Technology Development Phase A, the project determined the best way to quickly acclimate potential industry partners to the WFIRST mission, the WFI instrument and the driving requirements was a 3 step process. The first step was a short, 4 month study where offerors would be provided the WFI design produced by GSFC for the MCR. A Request for Proposal (RFP) for a fixed price contract was released in January 2016, with the contract being signed in March 2016 and the final study report delivered in July 2016. This relied on GSFC being able to meet with the offerors and describe in detail the design of WFI at that point as well as to inform them of the requirements associated with the design provided. The end product from the short study was a report which would detail the cost, schedule, and technical abilities of the offeror to implement the GSFC design, with a minimal focus on deviating from the design given the relatively short period of performance. Two offerors submitted proposals and were selected to complete the study.

The second step was a longer 6 month study focused on ensuring a complete and robust set of requirements. The offerors were provided a requirements document and the final deliverable was an internal Subsystem Requirement Review and a study report with the offeror's design that met requirements along with cost, schedule, technical challenges, and facility needs. It was expected, but not required, that the same organizations submitted proposals to both studies to ensure continuity and knowledge transfer. The RFP was released on August 2016, contracts signed in November 2016 and the study report delivered in May 2017. Three offerors submitted proposals and two were selected to complete this study.

The final step was a full and open competitive procurement for a major portion of the WFI instrument based on a robust and vetted set of requirements developed as part of the second study. The RFP was released in September 2017, with proposals due about one month later in October 2017. Again, the same two offerors as with both of the previous studies submitted proposals. After the program officially entered the Preliminary Design and Technology Completion Phase B, in May of 2018, the contract was awarded to the Ball Aerospace. During this entire two and a half year period however, the MCR WFI requirements and design went through some rather drastic changes, making the freezing of requirements for the final competitive RFP all the more challenging.

IV. Design and Requirement Changes Throughout Procurement

During the first study, internal discussions within the project and with potential industry partners led to a major trade study to consider moving the powered M3 mirror external to the WFI volume. As discussed in Section II, a third powered mirror (M3) in the overall three-mirror anastigmatic design (PM-SM-M3) was located within the WFI instrument volume. Consideration was given to mounting the M3 to the metering structure for the rest of the telescope instead of internal to WFI; this consideration was driven primarily by the revelation of the difficulty in providing complex optical verification simulators for both the instrument and the telescope[1], since neither organization would have a "clean" image based on the system overall three mirror anastigmatic design; the telescope would output the image after two passes through powered optics (Primary and Secondary mirror) and the input to WFI would need this distortion prior to the third powered mirror contained within WFI. In essence the output of the telescope would need to be optically processed through a third powered surrogate mirror to verify optical performance. Similarly, the optical input to WFI would need to be distorted by 2 powered optics surrogates for the primary and secondary mirror effects. Deviating from this baseline necessitated a complete redesign of the optical layout, which was a major disruption to the design evolution but resulted in a design that was easier to verify.

With a major redesign of the optical layout, the possibility of a passive design was again investigated as the project has always had concerns with the schedule risk of the cryocooler. This placed a requirement on the optical layout to be as far outboard as possible to minimize the distance to potential radiator locations to passively cool the detectors. After considerable efforts and design iterations, the WFI/WFIRST architecture design closed around the requirements. Furthermore a number of other design changes were also implemented throughout this design process. These are included in the table below along with their impact on the thermal subsystem

Design Change	**Impact on Thermal**
Re-layout of Optical design to move tertiary mirror out of WFI optical layout	Allow passive option to be investigated, change in optical bench shape, significant thermal gradient introduced on optics in Element Wheel
Change from active cryocooler to passive radiator for detector cooling	Reduction in instrument power (no cryocooler), increase in radiator size (Facility Radiator)
FPE avionics moved from warm spacecraft module to cold instrument module	New radiator needed, isolation needed
Removal of Auxiliary Guider	Removal of cooling need for AG detectors
Change from Frame to Strongback and Flexures to support MOSAIC plate	Better thermal isolation possible
Introduction of additional cooling requirement on cold optics baffle assembly	Addition of new thermal zone (new radiator and heatpipes). This was enabled by the new optical layout
Change Detector Readout speed	Increased SCE power
Lowered Detector Operating Temperature by 5K	Increased parasitics, additional cooling needed
IFC Descoped	Reduced cooling needs
Increase number of elements in Element Wheel	None

Table 1 – Major Design Changes to WFI since MCR

The GSFC design[2] was evaluated in a Thermal Engineering Peer Review in December 2017, about 2 months after the final competitive proposals were due, but during the proposal evaluation blackout period. While it was known that this design would not go forward, it was necessary to continue along the normal project life cycle until a new vendor was selected. This design is based on the updates listed above and is shown in Figure 2 below. The incoming light from the telescope enters the instrument, passes through the selected element in the Element Wheel, and is reflected off an actuated flat fold mirror to the Focal Plane Assembly with the 3x6 array of H4RGs. The shape of the enclosure and optical bench changed, but the bench was still cooled by direct connection to a dedicated

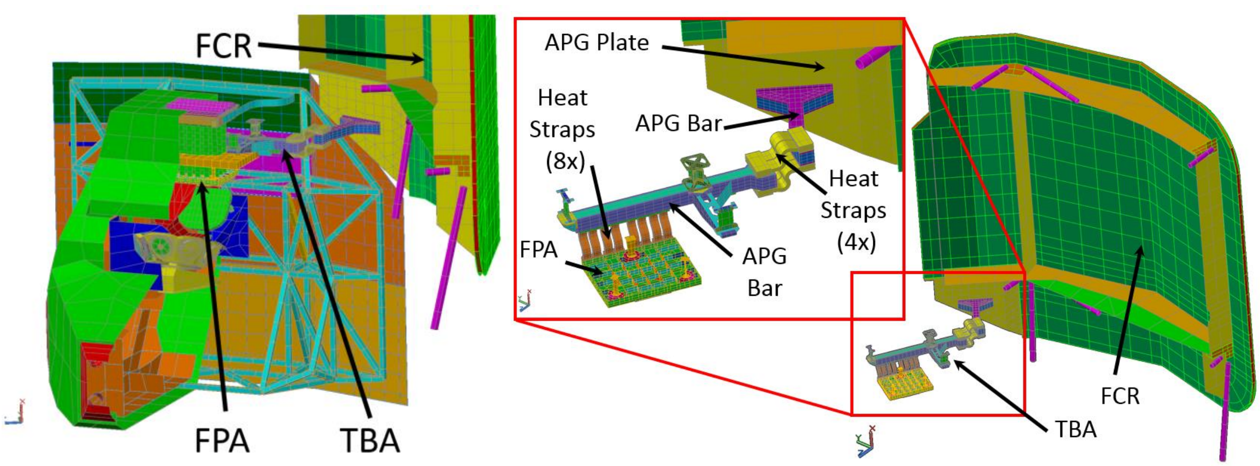

Figure 2. WFI Cutaway View (SRR GSFC Design): *cutaway view of WFI instrument showing the Focal Plane Assembly, Thermal Bus Assembly, and Facility Cryogenic Radiator*

radiator via ethane heatpipes. The Cold Optics Baffle Assembly was now cooled via its own dedicated radiator and heat pipe connection. The SCEs were cooled by their own dedicated radiator and heatpipe system and the FPE was mounted directly to its own radiator. The FPA was now cooled by a Thermal Bus Assembly (TBA) link which connected to a large Facility Cryogenic Radiator (FCR). This TBA consisted of 8 straps connected to the FPA, with the other ends connected to an Annealed Pyrolytic Graphite (APG) bar, then to 4 more straps, then to another APG bar and plate, and finally to the FCR. The connection between the TBA and FCR was made serviceable so that the instrument could be replaced as per the mission requirements.

Table 2 shows the progress of the studies and the competitive procurement in parallel with major design changes and internal reviews. Neither of these paths is independent of the other and the effort to redo the optical design was driven by input from vendors from the first study. The change to passive cooling happened during the second study and both vendors had inputs into the requirements for a passively cooled design.

Event	Vendor	GSFC
Mission Concept Review	Dec 2015	
Study 1 RFP	Jan 2016	
Key Decision Point A		Feb 2016
Study 1 Contract	Mar 2016	
Relocate FPE to Cold Module		**Mar 2016**
Introduction of additional cooling requirement on cold optics baffle assembly		**May 2016**
Change from Frame to Strongback and Flexures to support MOSAIC plate		**May 2016**
Change Detector Readout Speed		**June 2016**
Study 1 Report Deliverable	July 2016	
Re-Layout of Optical Design		**July 2016**
Study 2 RFP	Aug 2016	
Change to Passive Cooling		**Oct 2016**
Study 2 Contract	Nov 2016	
Study 2 Report Deliverable	May 2017	
Competitive Procurement RFP	Sep 2017	
Proposals Due	Oct 2017	
Lowered Detector Operating Temperature by 5K		**Dec 2017**
Thermal Engineering Peer Review		**Dec 2017**
IFC Descoped		**Apr 2018**
Key Decision Point B		May 2018
Award	May 2018	
WFI System Requirements Review (SRR)	August 2018	

Table 2 – Timeline of Major WFI Milestones

V. Procurement Process and Lessons Learned

The same team of people was responsible for interfacing with potential industry partners and driving the WFI design and requirements. With a large number of design changes (and requirements changes) after MCR and the large scope of some of them, this placed considerable demands on the supporting staffing to complete trade studies quickly. A total of approximately 15 unique trade studies (thermal related ones highlighted in Table 2) for WFI were completed between MCR and the competitive procurement. As these trade studies were completed, the requirements were also updated based on the new high level architecture designs. These requirements were then flowed into the requirements document to accompany the competitive procurement. During all these efforts the same team or people were travelling to interface with the potential industry partners and monitor the progress on the study contracts and answer any questions industry partners may have had. While the team handled the workload well, it did require considerable effort on many people's parts to make this approach work.

Lesson Learned: Project schedules and staffing plans that are not adjusted after a major procurement change approach can place considerable strain on project teams with the additional, unplanned workload.

The study approach did have a major benefit of identifying considerable challenges in the MCR design that may not have been adequately recognized at the time. The identification of the complexity needed for optical verification units led to a major architectural change of moving the tertiary mirror outside of the WFI volume. This new optical layout further enabled a second major architecture change that allowed for passive cooling of the detectors, which removed a major schedule risk to produce a cryocooler. With these trade studies completed earlier in the project life cycle and with the advocacy of potential industry partners, it is likely that considerable cost and schedule may have been saved due to accepting these difficult changes early instead of discovering and addressing them later.

The inclusion of technical inputs and evaluation for potential industry partners can be likened to the concept of crowdsourcing, where multiple organization have inputs into a design rather than just one. If the cost of the studies is relatively small, their value to leverage the knowledge base of potential industry partners to ensure the technical, cost, and schedule risks are properly identified prior to a major procurement may well be worth the cost. Determining these risks early allows for changes to requirements before they become costly to change later in the project life cycle. Furthermore, the studies also give potential industry partners more time to understand the driving requirements and scientific motivations. With the two industry partners for WFI being engaged for many months prior to the competitive flight procurement, both organizations had time to refine their design and begin early rounds of optimization. They also had the benefit of interactions with the customer who could identify potential weaknesses or misunderstandings of the requirements. Rather than simply responding in a few months to a heretofore unseen RFP and set of requirement, the potential industry partners had more time to refine and optimize a design resulting in a better proposal being delivered to the customer. While there is only one organization that was awarded the contract, the studies allowed multiple organizations to have inputs and feedback on their proposed designs and requirements prior to the instrument final competitive procurement.

Lesson Learned: Having multiple organizations review preliminary requirement sets prior to a competitive procurement results in a more thoroughly vetted set of requirements for a design

Lesson Learned: Having many design iterations and trade studies completed earlier in the project life cycle reduces the potential for future scope, cost, and schedule growth if the requirements are well established and at least one design identified to meet them.

This knowledge sharing between a Government customer and potential industry partners does carry with it some risk to the government to remain impartial and to protect the intellectual property and designs of potential industry partners. Design elements proposed by other organizations cannot be used in the Government's design or requirements unless traceability exists that the Government had examined this possibility earlier. Even if the proposers design feature is so clearly advantageous, it may not be used in the Government's design and may not be divulged in any manner that would compromise the originating organization's competitive advantage.

Furthermore, proprietary processes and techniques (such as a proprietary coating) may not be specified in the requirements. To do so raises an Organization Conflict of Interest (OCI). An OCI would result if the Government utilized a contractor's design or intellectual property (IP) in a competitive procurement. An example of an OCI in the category of "Biased Ground Rules", is when a contractor, as part of its performance of a government contract, has in some sense set the ground rules for another government contract and could skew future competitions to their advantage; and by virtue of its special knowledge of the agency's future requirements, would have an unfair advantage in the competition for those requirements. (FAR 9.505-2). A contractor would have to recuse themselves from the competition if the Government was to ever utilize a contractor's design or IP in a competitive procurement.

The Government must exercise extreme care to not compromise any organization's competitive advantages, proprietary processes and techniques, and design features to remain an impartial arbiter of the final proposals.

Lesson Learned: Specific intellectual property of the proposers must be carefully guarded and not used to specify requirements in order for the government to maintain a neutral stance during a competitive procurement.

One drawback of the study approach employed for WFI was the potential for biasing the proposer's design. Having provided potential industry partners with the Government's solution to the requirements may have inadvertently biased them towards a similar design. This has the potential to hamper innovation since deviations from the provided design must be weighed against the perception that the customer may consider other designs riskier. A proposer may consider a design superior to the provided design and choose to not pursue it further due to perceptions that the customer may consider it risky because it does not closely align with the provided design.

Lesson Learned: Providing the customers design solution to a set of requirements may hamper the innovation of the proposers' designs, since deviation from the provided design may appear risky to the customer and proposers would need to weigh that consideration.

The decision to include an industry partner occurred relatively late in the conceptual phase of the program and was followed by a two and half year competitive process. Although the multiple studies that allowed Government/industry interaction and the RFP process yielded improvements in the final set of requirements and improvements in the design evolution that ultimately resulted in cost savings to the Government, efficiencies in the process could have condensed the overall schedule. The decision to involve industry came shortly before the Mission Concept Review. Prior to that, all indications were that GSFC would design, develop, and test the instrument in-house. In the pre-Phase A activities, a number of design cycles were performed with efforts focused more on evolving the design to a high level set of requirements rather than developing robust requirements necessary for a competitive procurement. This shift from design and requirements evolution in parallel to a pure focus on requirements solidification was a significant departure from the project evolution to that point. Having to both evolve the requirements to a maturity level sufficient for procurement as well as continue to evolve a design to meet project milestones post Key Decision Point A resulted in some efforts that were abandoned once an industry partner came on board. Had the involvement of industry been identified earlier, the focus could have shifted sooner and reduced the time to complete the competitive procurement and involve an industry partner sooner in the project life cycle.

Lesson Learned: Decide procurement strategy as early as possible to fully engage industry earlier in the conceptual phase, shorten the overall procurement process, and maximize community support.

The studies, in particular the second longer one that focused on ensuring a complete and robust set of requirements, allowed industry to better understand the Government needs for WFI. By exploring the rationale behind requirements, answering questions, and providing clarification on how to really interpret requirements, the Government was able to refine the requirements so that there is little ambiguity in their intent. Reducing ambiguity results in solutions that have the potential to reduce risk. Requirement clarifications were, of course, shared with both study contractors and appeared in the flight hardware solicitation that followed the second study. Without industry participation, these refinements might not have occurred. The studies enabled the industry partners the time necessary to explore the requirements interpretation space and ask meaningful questions that a typical question/answer period for an open RFP does not accommodate. Often, offerors are reluctant to pose questions due to the regulations which require all questions submitted by any offeror be made public to all offerors; offerors may feel that posing questions may reveal an aspect of their design or a competitive advantage that they are wary of identifying. The less formal studies allowed for a more open dialog between potential offerors and the government and likely resulted in more robustly reviewed requirements. In this case, the requirements document changed over time from a build-to-print to a design-to-performance specification. Performance based specifications are more difficult to write, especially in a way that the true intent of the requirements is interpretable, but they do widen the trade solution space.

Lesson Learned: To fully take advantage of a competitive study and organizational diversity of thought, a performance based requirements document is required as opposed to a build-to-print specification based on a particular point design.

Since one of the study participants was chosen as the industry partner, less time was spent coming up to speed once the flight hardware program was started. The studies allowed industry to fully understand the project and work that had been accomplished to date. Once the flight contract was awarded, there were only 11 weeks until the instrument System Requirements Review (SRR). Without the knowledge from the study, it would have been very difficult to execute a successful SRR in such a short time after contract award. Furthermore, the knowledge gained in the study allowed other design trades to be suggested that could potentially be of benefit to the Project.

Lesson Learned: The study process reduces the time on the learning curve after final contract award for the chosen industry partner.

For example, shortly after SRR, a NASA and Ball trade was completed to evaluate the radiator architectures that could be used to cool the focal plane. With knowledge gained in the study, the Ball design eliminated the actuated fold mirror in the GSFC design and instead moved the actuation to the focal plane. This change resulted in the focal plane being located further outboard, which was of considerable benefit to the thermal design by shortening the distance to a possible outboard radiator location. A trade study was conducted to evaluate if the FCR could effectively be moved to be part of the instrument rather than mounted to the observatory. The shorter distance helped reduce the thermal resistance between the focal plane and the radiator, enabling a smaller radiator for cooling the focal plane. Furthermore, this smaller radiator area solution was further reduced due to smaller flexures with less mass to support and less radiative area for heat leaks through the backside insulation. The overall observatory mass was reduced, the serviceability of the instrument was simplified, and test verification risk was reduced by allowing complete instrument testing by not having to simulate the spacecraft mounted radiator. However, because there were 10 months between the end of the second study and flight hardware contract, design work on the Government design continued and there was no interaction between the Government and the study contractor or potential bidders during those 10 months, it did take additional time and effort to incorporate Ball's design into the overall mission design once the contract was awarded.

Lesson Learned: Long duration contractual blackout periods during the conceptual design phase may reduce the efficiency of the design cycle by delaying the implementation of industry partner's features into the overall observatory design.

VI. Current WFI Thermal Design

The current thermal design is shown in Figure 3 for WFI and features a radiative enclosure around a compact, composite tube optical bench. The element wheel, now called the Transmissive Optics Selection Assembly (TOSA), changed from a bowl shape to a flat disk and accommodates a total of 12 elements. The IFC channel was removed, but a prism was added as one of the elements to the TOSA to perform the spectroscopy that was previously handled by the IFC. The FPE was relocated to the top of the instrument along with its own dedicated radiator (shown in red). The radiative enclosure around the bench is cooled by its own dedicated radiator (dark green) and includes connections to the COBA (not pictured) between the element wheel and focal plane as well as the SCEs. The focal plane is now connected via high conductivity bars to its own dedicated focal plane radiator (cyan) which is mounted to the instrument but thermally isolated. Lastly, the latch locations for the instrument were changed to better accommodate the new optical layout and supporting structure.

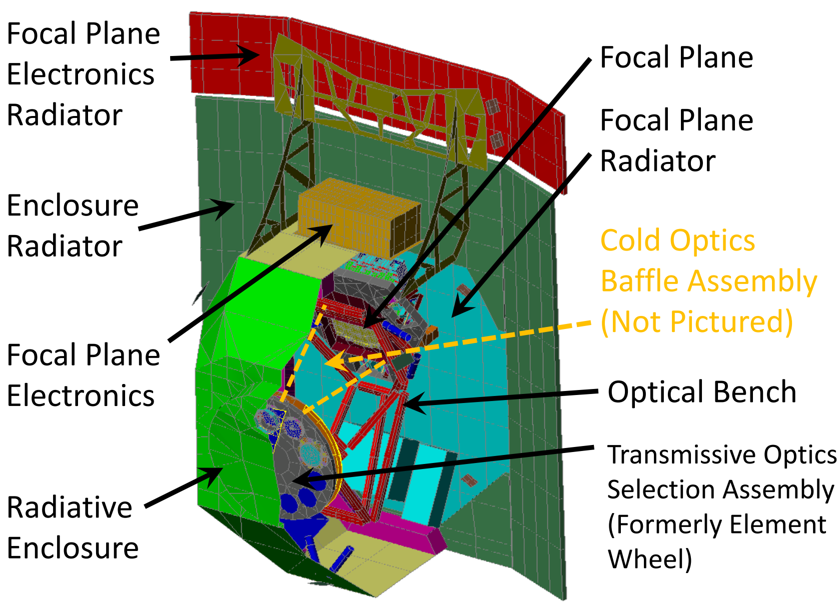

Figure 3. Post SRR WFI Thermal Design: *cutaway view of WFI instrument showing the Radiative Enclosure, frame Optical Bench, and Focal Plane, now cooled by its own instrument side dedicated radiator.*

VII. Conclusions and Path Forward

The design evolution of the Wide Field Instrument on WFIRST has undergone many twists and turns to get to the current design. However, all the trade studies performed by GSFC, the interactions with both potential and awarded industry partners, the thorough vetting of the requirements, and the procurement process have yielded a mature design based on solid requirements and a focus on verification. While the change from a GSFC in house design to a design with a major contribution from industry was not planned from the outset, the additional scrutiny that the design was given as a result of the industry studies and competitive flight procurement resulted in difficult decision being made that produced a superior design to what was presented at the Mission Concept Review. While considerable time and effort burdens were placed on the WFI team to both proceed with the in house design in parallel to interfacing with potential industry partners and maintaining confidentiality of competition sensitive design aspects, the end result of both proposals submitted were improved designs. Ball Aerospace was selected after a nearly 6 month proposal evaluation period and WFI successfully passed its System Requirements Review in August 2018.

The design underwent another major transformation, moving the functionality of the Facility Cryogenic Radiator from the spacecraft responsibility to instrument responsibility, thereby making an instrument design that can be fully thermally tested and qualified by the industry partner without the need for a radiator simulator. The design continues to mature with a planned Preliminary Design Review in mid 2019. Upon launch, WFIRST will seek to answer some of the greatest questions about dark energy and the expansion of the universe and the Wide Field Instrument will be a key component to unlocking those secrets.

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Lessons Learned

Project schedules and staffing plans that are not adjusted after a major procurement change approach can place considerable strain on project teams with the additional, unplanned workload.

Having multiple organizations review preliminary requirement sets prior to a competitive procurement results in a more thoroughly vetted set of requirements for a design

Having many design iterations and trade studies completed earlier in the project life cycle reduces the potential for future scope, cost, and schedule growth if the requirements are well established and at least one design identified to meet them.

Specific intellectual property of the proposers must be carefully guarded and not used to specify requirements in order for the government to maintain a neutral stance during a competitive procurement.

Providing the customers design solution to a set of requirements may hamper the innovation of the proposers' designs, since deviation from the provided design may appear risky to the customer and proposers would need to weigh that consideration.

Decide procurement strategy as early as possible to fully engage industry earlier in the conceptual phase, shorten the overall procurement process, and maximize community support.

To fully take advantage of a competitive study and organizational diversity of thought, a performance based requirements document is required as opposed to a build-to-print specification based on a particular point design.

The study process reduces the time on the learning curve after final contract award for the chosen industry partner.

Long duration contractual blackout periods during the conceptual design phase may reduce the efficiency of the design cycle by delaying the implementation of industry partner's features into the overall observatory design.