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Results of the AIAA 2017 Phobos Base Student Design Competition

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The AIAA Life Science and Systems Technical Committee (LSSTC) and the AIAA Space Architecture Technical Committee (SATC) jointly organized and sponsored the Phobos Base Student Design Competition. The design brief conveyed a dual focus on the Environmental Control and Life Support Systems (ECLSS) engineering and the Space Architecture for design of the base and habitability for the space living and working environments. This paper presents the results of the winners in the undergraduate and graduate student categories. The purpose of the Phobos Base design competition was to develop an integrated solution for the next step in developing Mars exploration architecture: the Phobos surface base. Phobos base will support exploration of Phobos, the remote exploration of Mars, and the eventual staging of human expeditions to the Mars surface.

Nomenclature

Δv = "Delta Vee," Change in Velocity
ECLSS = Environmental Control and Life Support System
EUS = Exploration Upper Stage
EVA = Extravehicular Activity
ICES = International Conference on Environmental Systems
ISS = International Space Station
LMO = Low Mars Orbit
LSSTC = Life Sciences and Systems Technical Committee
MDAV = Mars Descent-Ascent Vehicle
SATC = Space Architecture Technical Committee
SLS = Space Launch System
UH = University of Houston
UVM = University of Vermont

I. Introduction

THIS Phobos Base Student Design Competition presented two foci to the participants: to design the architecture for a habitable base in deep space and to design the environmental control and life support system to support the crew in that base. The two AIAA Technical Committees each contributed expertise to their respective portions of the design brief. The aim was to encourage future life support engineers and space architects to learn to work together on a common project or mission.

The major mission design challenge in staging humans to Mars concerns what to do when a spacecraft carrying a crew, a habitat, or other payload arrives in cis-Martian space. The two conventional options are to circularize into low Mars orbit (LMO) before landing or to attempt direct atmospheric braking, entry, descent, and landing. This

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design competition addresses the alternative of creating a logistical and scientific base on Phobos, the larger and closer of Mars' two moons. This base would host and support crews in transit to Mars and returning from Mars to Earth.

The major human support challenges of long duration microgravity flights include the effects on human systems adapting/deconditioning including pressure in the eyes from body fluid redistribution, bone demineralization, loss of muscle mass, and general deconditioning. Thus, a major focus is to provide human health and habitability maintenance regarding microgravity and surface environments while minimizing health risks through enhanced radiation shielding and microgravity countermeasures. As a probable captured carbonaceous chondrite asteroid that may contain as much as 13% water by mass, Phobos may also provide a source of life support and propellant consumables, including fuel for a reusable Mars Descent/Ascent Vehicle (MDAV). A critical advantage of Phobos Base would be its contribution to making a strong interplanetary infrastructure in deep space, which would make Mars exploration more sustainable over a long-term of 50 years or more.

In order to make the reports from the student teams as readily comparable as possible, the Competition Design Brief prescribed the outline in which they should write their submission, with a 100-page limit. The students would decide how much text and illustrative figures to place in each title or subtitle within the outline.

In presenting this overview of the results, the objective is not to show a rigorous, side-by-side comparison, but rather to illustrate the wide variety of strengths that the student teams displayed in what they learned. In this way, these results illuminate the many different areas of inquiry they pursued during their design project. This approach also helps to show the many complex dimensions of staging a human mission to Mars or Phobos, that often do not appear in the abundant advocacy-driven studies.

II. Undergraduate Winners

The two undergraduate winners were the University of Houston, Sasakawa International Center for Space Architecture for first place, and the Institute of Engineering, Tribhuvan University, Kathmandu, Nepal. The participants from the University of Houston were: Timothy Bishop, Victor Kitmanyen, Thomas Lagarde, and Zachary Taylor. Their Faculty Advisor was Assoc. Prof. Olga Bannova, Ph.D. The participants from Tribhuvan University, who called themselves Team Phobians, were Arjun Magar, Raj Kumar Gurung, Rajan Bhandari, and Sanjeev Adhikari. Their Faculty Advisor was Prof. Sudip Bhattrai.

A. University of Houston "Phari Base"

The University of Houston (UH) team named their project "Phari Base," for reasons they did not explain. The UH project displayed a strong familiarity with recent and current space exploration hardware and technology. Their approach showed an understanding of established system engineering approaches popular with NASA. The *Phari* team saw their design concept as analogous to the International Space Station (ISS):

> The crew at Phari Base must be prepared to receive both crew and supplies from a multitude spacecraft that may arrive at almost any time to Phobos. This is analogous to the crews onboard the ISS where there are multiple supply visiting vehicles and crew transfer vehicles that dock with the ISS on a regular basis. The same can be assumed for Phari Base, where visiting vehicles carrying supplies will be sent periodically and may use any class of mission that is the most efficient method of delivery. Mars bound crews may arrive less frequently, however, since the base is assumed to expand its capabilities at some point in the future, crews can expect more traffic to flow through the base and thus should be prepared for these operations (p. 11).

Despite this analogy to the ISS — or perhaps because of it — the *Phari* team did not appear to recognize that these launches of cargo and crew to Phobos would depend upon the Hohmann minimum energy transfer orbit windows that open up every 22 months between the Earth and cis-Mars space, including its two moons. This analogy to the ISS carries through to the structural organization of *Phari Base* around a segment of truss.

> The transfer of the *Phari Base* infrastructure will happen in two stages. The first stage will be to launch the truss assembly to Phobos. The rationale behind this activity is to ensure *Phari Base* has an established structure on Phobos that is secured to the bedrock. Furthermore, the truss assembly itself is cheap relative

to the entire base and will only require one SLS Block 2 launch. This makes the truss assembly expendable in the event the system fails; if that were to happen, telemetry would be sent back to ground control in order to engineer a more robust system. Such measures are justifiable considering how unpredictable Phobos is, even with reconnaissance probe mapping the surface (p. 23).

FIGURE 1 shows an exploded axonometric view of the *Phari Base* concept with its central truss. The crew quarters module was based upon the TransHab inflatable module concept.

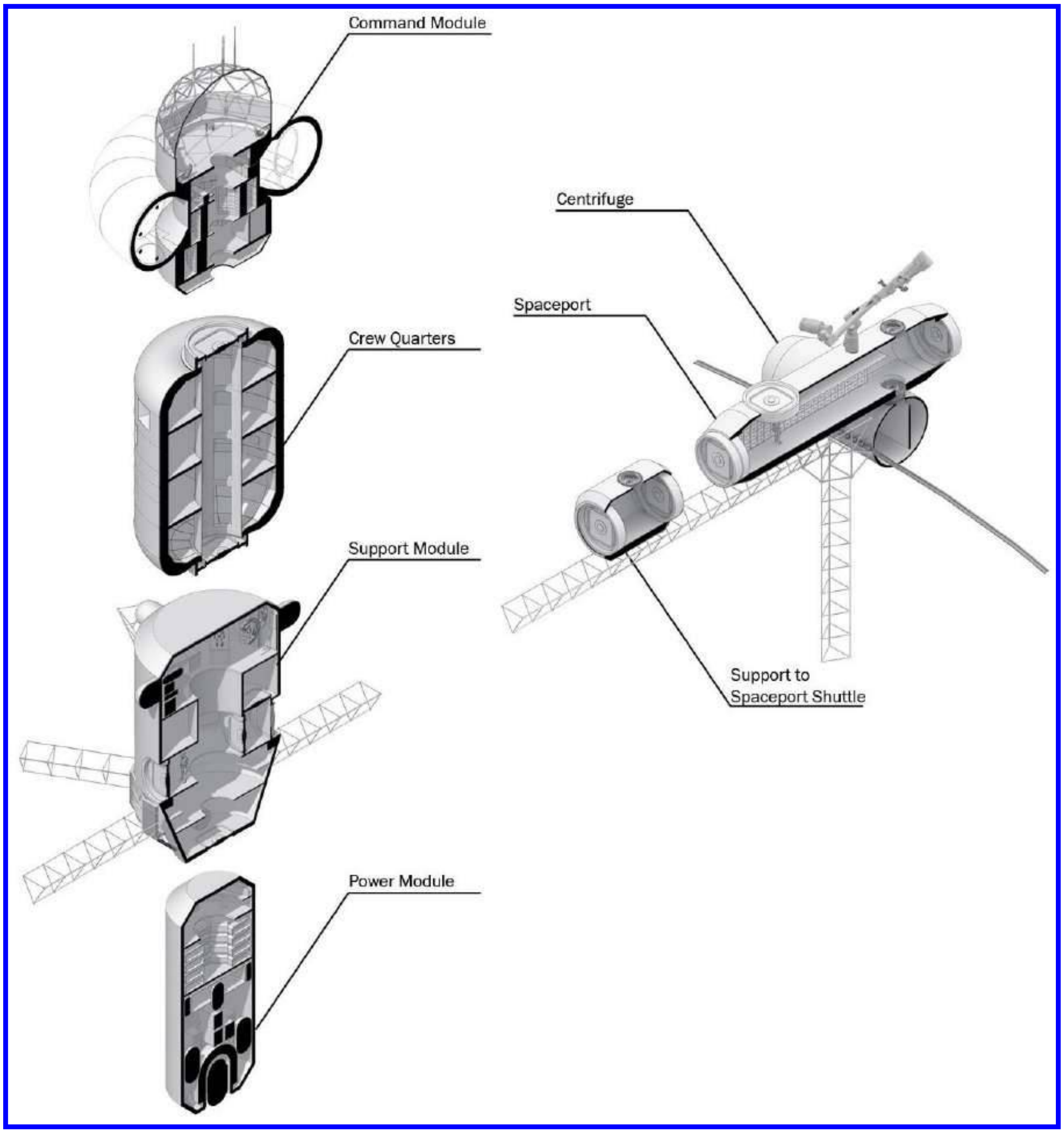


FIGURE 1. Exploded view of the *Phari Base* architecture, showing the centrality of the tetrahedral truss structure for anchoring and connecting the modules.

The *Phari* team provided a countermeasure against microgravity in a torus wrapped around the crew module. Their countermeasure scheme involved rotating the *Phari Base* configuration, and the crew would enter the torus to experience higher gravity levels. FIGURE 2 shows a view of this configuration, along with some details of the dome and galley area.

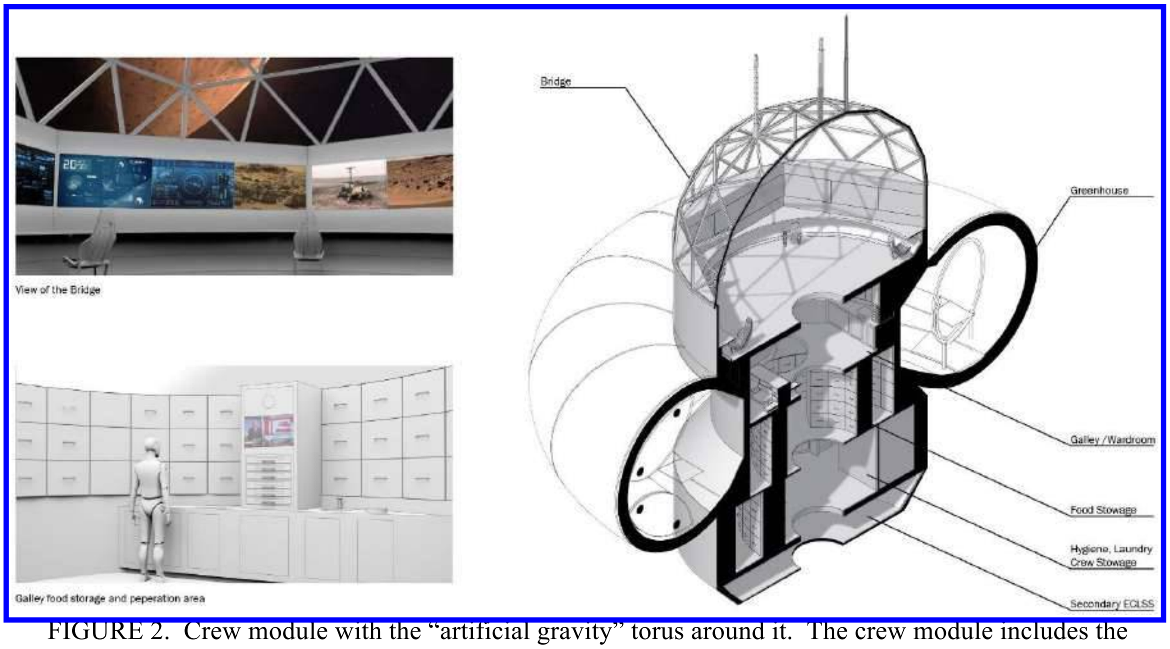


FIGURE 2. Crew module with the "artificial gravity" torus around it. The crew module includes the geodesic dome area, galley, and all the other crew accommodations.

Overall, the *Phari Base* concentrated far more on the Space Architecture than upon the life support engineering, although they made a valiant attempt at micro-g countermeasures. The design and presentation of the habitable architecture was clear and sophisticated. What is more remarkable, the Space Architecture aspects are almost self-explanatory. The *Phari Base* included some estimates for ECLSS, but they were not nearly up to the level of the Architecture, which showed true professional capability.

B. Tribhuvan University

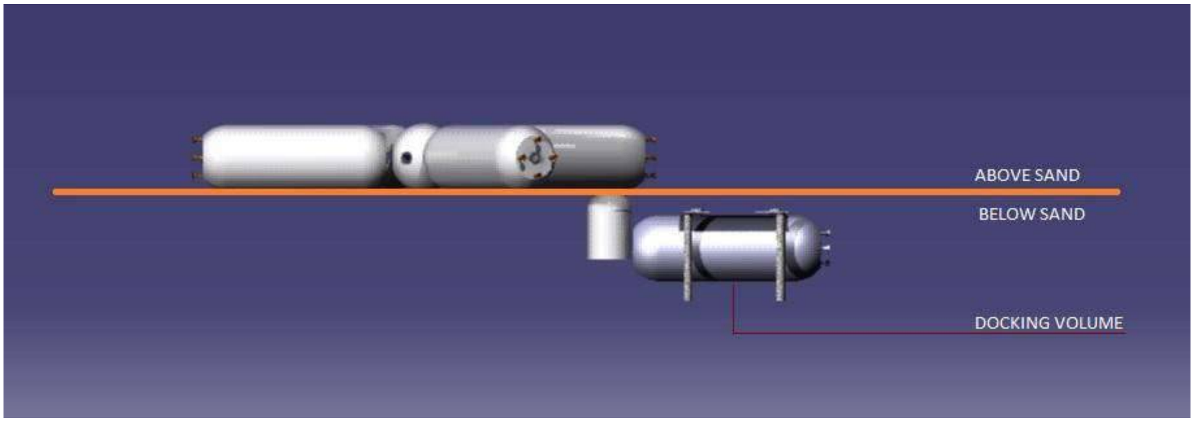


FIGURE 3. Transverse section-elevation of the Phobian Base, revealing the location of modules above and below the surface.

The *Phobians* from Tribhuvan University focused more on the engineering side of the project, providing detailed calculations for the astrodynamics and trajectories of the spacecraft taking their *Phobian Base* to cis-Mars orbit, including the calculation of velocity to enter and maintain Mars orbit before rendezvous with Phobos. The *Phobians* engaged in numerous discussions of the cost, mass, technical suitability and technology readiness, starting from the launch vehicles, continuing through the astrodynamics of the trajectory and the maneuvers at Mars and Phobos, and finally detailing the engineering for the ECLSS. This passage describes their reasoning for selecting the Space Launch System (SLS) Block 1B with the Exploration Upper Stage as their launch vehicle of choice.

Considering this Payload capacity, the whole base transportation completes in six launches. Since, in a single launch window all six launches is impossible to occur due to inability to develop six rockets within the given time as well as the difficulty in maneuvering of these launch trajectory such as they don't intercept each other. Thus, the whole base transportation extends between 2018 to 2026 with the first launch on May 2018 and arrival of last base module on Phobos on early 2026. Increase in payload for minimum fuel consumption and minimum dry mass of rocket is the primary issue in the development of the rockets. SpaceX is making rockets on minimum budget constraints with its maximum payload to mars being 13.5 metric tons by Falcon heavy. Since this Payload capacity is much lower than demanded by our mission plan, SLS was chosen. SLS Block 1B uses a more powerful second stage called the Exploration Upper Stage (EUS). On January 2015, test firing of RS-25 engines began for use on SLS and continued in 2016 and 2017 showing positive test results. This signifies the availability of SLS Block1B for the Phobos Base Transportation.

The *Phobians*' habitable architecture centered on a variation of the NASA/Bigelow Aerospace TransHab-type module. FIGURE 3 shows a transvers section-elevation of the *Phobian Base*, revealing the "docking volume" below the surface of Phobos and the TransHab-derived inflatable modules above the surface. These modules radiate from a central, spherical hub.

FIGURE 4 presents a perspective view of the *Phobian Base,* showing the layout of the TransHab-derived inflatable modules, berthed radially around the central spherical hub. What appear to be solar arrays stand on the surface in a circle around the *Phobian* site. What looks like a multi-bay radio antenna projects upward from the central hub. Spacecraft or utility modules dock to the ports at the distal ends of the inflatable modules.

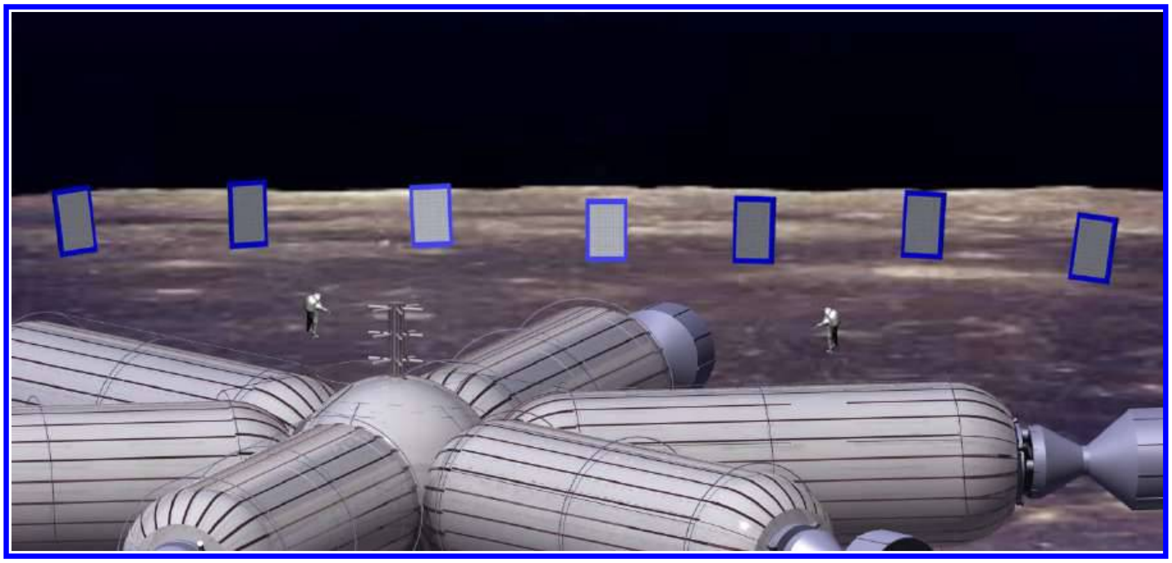


FIGURE 4. Perspective view of the Phobian Base, showing the radial arrangement of the pressurized modules around the spherical central hub, and spacecraft docked to ports at the distal ends of the modules.

FIGURE 5. Shows a larger, transparent view of the Central Hub, showing three locations for observation or operation stations. Although FIGURE 3 shows the Central Hub as appearing to incorporate radial pressurized berthing ports around the equator, they do not appear in this view. The internal division of the spherical volume suggests a separation of the observation and operations functions; certainly the astronomical and Mars-facing positions require pointing in different directions. However, why the Rover Operation Station does not share the same hemisphere with the Mars Observation Station, since they are both focused on Mars, is not explained.

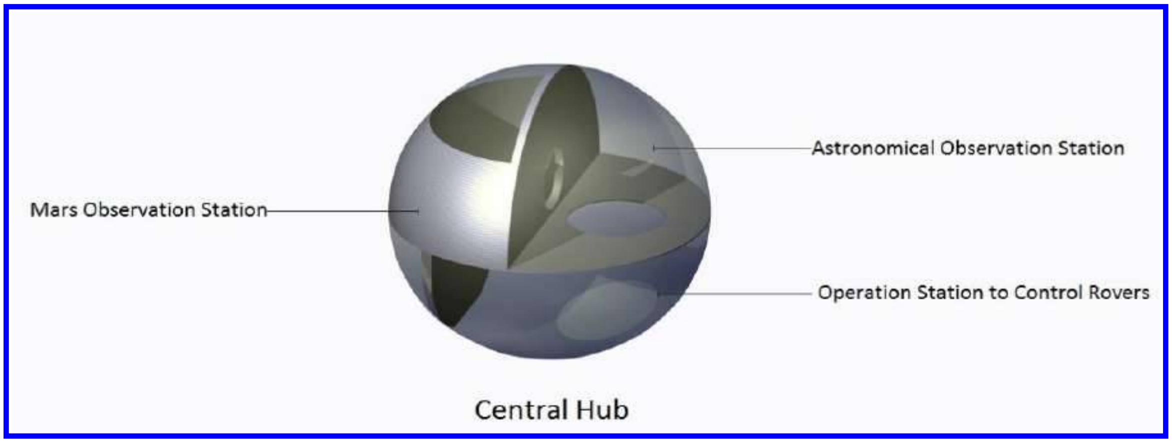
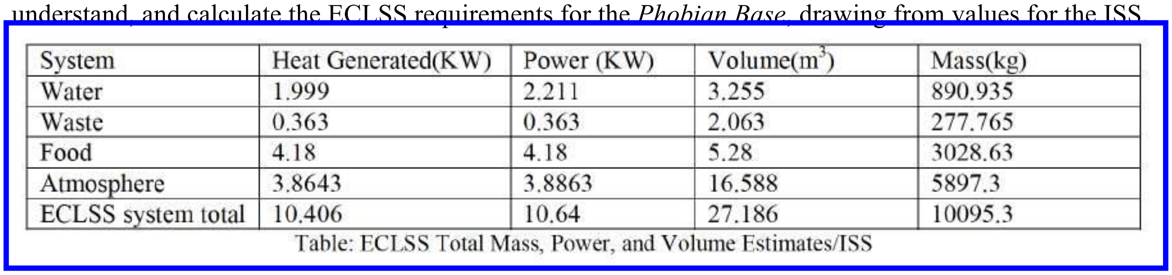


FIGURE 5. Transparent View of the *Phobian Base* Central Hub

FIGURE 6 presents the *Phobians*' table of ECLSS Mass, Power, and Volume Estimates, apparently derived in some fashion from comparable numbers from the ISS. This table shows an important effort to investigate, understand, and calculate the ECLSS requirements for the *Phobian Base*, drawing from values for the ISS.



System	Heat Generated(KW)	Power (KW)	Volume(m^3)	Mass(kg)
Water	1.999	2.211	3.255	890.935
Waste	0.363	0.363	2.063	277.765
Food	4.18	4.18	5.28	3028.63
Atmosphere	3.8643	3.8863	16.588	5897.3
ECLSS system total	10.406	10.64	27.186	10095.3

Table: ECLSS Total Mass, Power, and Volume Estimates/ISS

FIGURE 6. Phobian Base Table of ECLSS calculations.

The *Phobians* did a heroic job of addressing all the engineering parameters of the Phobos Base design brief. They covered the Astronautical and ECLSS calculations. They made an effort at providing a micro-g countermeasure using a lower body negative pressure system. Their entry in the competition is a promising start for the participants' careers.

III. Graduate Winners

The two graduate winners were the University of Vermont, for first place, and Wroclaw University, of Technology, Poland for second place. The participants from the University of Vermont were: Emmie Bolt, Greg Castaldi, Sami Connoley, Cam Ru_e-Deignan, Duncan Hacker Moritz Thali, Jacob Wainer, and Matthew Walton. The participants from Wroclaw University were Aleksander Gorgolewski, Anna Jurga, Leszek Orzechowski, Joanna Kuzma, Jan Popowski, and Bartosz Wasik. In addition, three individual students from other universities joined the Wroclaw team: Gordon Wasilewski from AGH University of Technology, Poland, Monika Lipinska, Lund University, Sweden, and David Conte, Pennsylvania State University, USA.

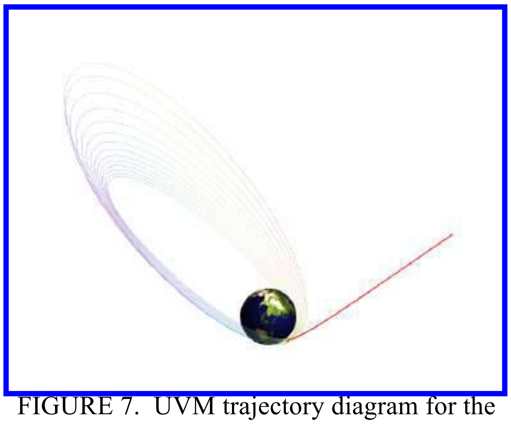


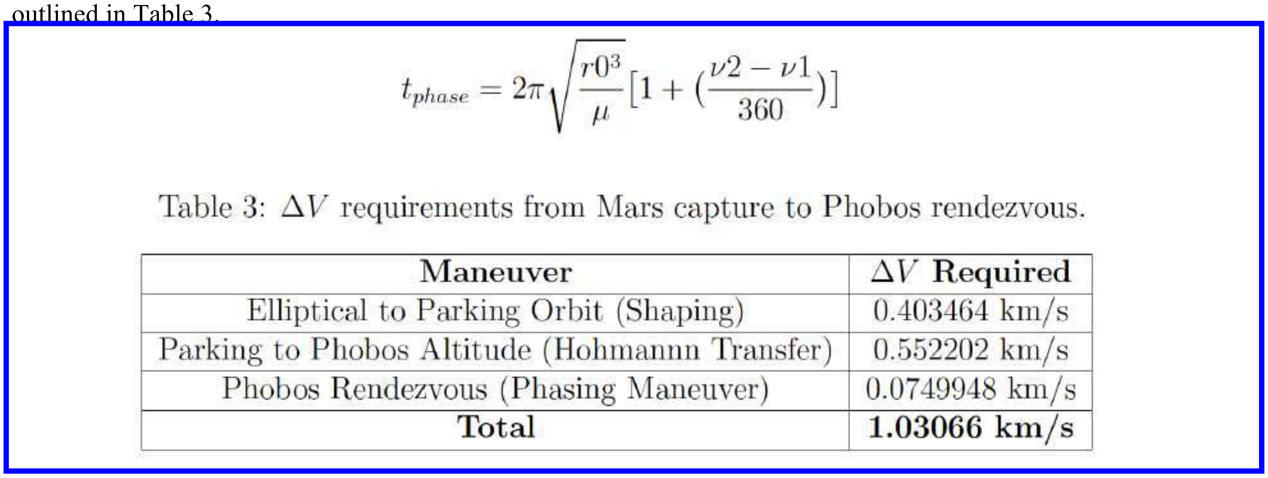
FIGURE 7. UVM trajectory diagram for the precession of the parking orbit at earth and departure to Mars.

A. University of Vermont

The submission from UVM displayed a significantly higher level of insight, sophistication, and understanding in engineering than the undergraduate submissions. UVM begins with an elegant discourse on the waiting period before departing the Earth and cis-lunar space. They describe the elliptical parking orbit about the Earth, its precession, and departure with excellent trajectory diagrams. FIGURE 7 shows the UVM departure trajectory diagram.

The trajectory adjustment upon arrival in the Phobos vicinity is even more impressive. The following passage explains the UVM approach and it relates to the calculation that follows in FIGURE 8 for the spacecraft to maneuver close to Phobos.

> In order to compensate for the angular discrepancy between the capsule and Phobos the craft will perform a phasing maneuver. In orbital mechanics it is well understood that satellites orbit slower when they are further from the central body. The capsule will take advantage of this fact to adjust its trajectory and approach Phobos. By firing an impulse normal to the orbit, away from Mars, the craft will experience a Δv of 0:0374974 km/s and enter a slightly elliptical orbit with a larger semi major axis than Phobos' orbit. While in this orbit, the spacecraft will travel with a slower angular velocity allowing Phobos to approach from behind.
>
> After 8:08592 hours Phobos and the craft will have the same true anomaly. This time of flight is calculated from Equation 5 where r0 is initial position and $\nu 1$ and $\nu 2$ are the true anomalies in degreed of Phobos and the craft respectively. At this point the craft will again make a Δv maneuver of 0:0374974 km/s, this time back towards Mars. The gravity of Phobos will begin to act on the craft and draw it in. As the capsule is slowly being accelerated towards Phobos it will use attitude control nozzles to control speed and guide itself to the appropriate landing location. The total Δv requirements for the entire process from Mars capture to Phobos rendezvous are outlined in Table 3.



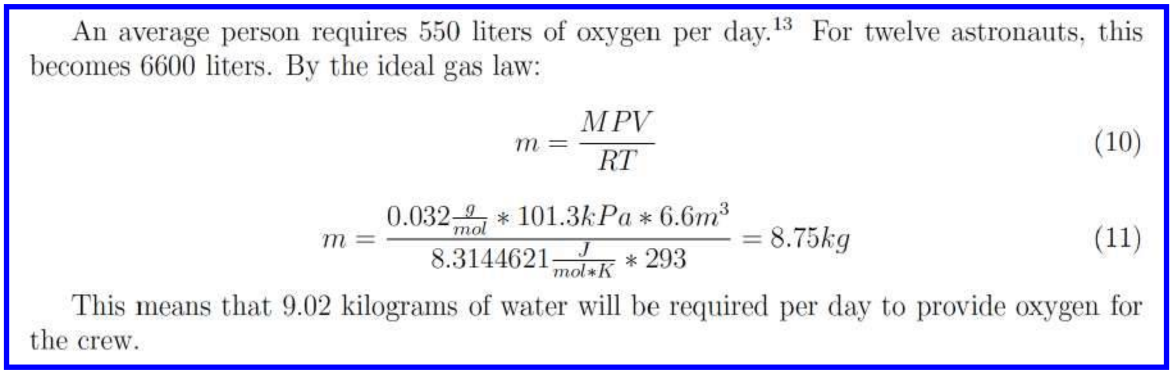
$$t_{phase} = 2\pi\sqrt{\frac{r0^3}{\mu}}[1 + (\frac{\nu 2 - \nu 1}{360})]$$

Table 3: ΔV requirements from Mars capture to Phobos rendezvous.

Maneuver	**ΔV Required**
Elliptical to Parking Orbit (Shaping)	0.403464 km/s
Parking to Phobos Altitude (Hohmannn Transfer)	0.552202 km/s
Phobos Rendezvous (Phasing Maneuver)	0.0749948 km/s
Total	**1.03066 km/s**

FIGURE 8. Δv requirements from Mars capture to Phobos rendezvous.

The UVM ECLSS calculations deserve notice; it appears that they developed their approach *from first principles* on their own and made some reasonable estimates. FIGURE 9 shows a detail from their report, detailing the calculation to estimate the required mass of water per day to generate sufficient O_2 to support crew respiration.



An average person requires 550 liters of oxygen per day.[13] For twelve astronauts, this becomes 6600 liters. By the ideal gas law:

$$m = \frac{MPV}{RT} \tag{10}$$

$$m = \frac{0.032\frac{g}{mol} * 101.3kPa * 6.6m^3}{8.3144621\frac{J}{mol*K} * 293} = 8.75kg \tag{11}$$

This means that 9.02 kilograms of water will be required per day to provide oxygen for the crew.

FIGURE 9. UVM calculation of the amount of H2O necessary to process to produce one day's worth of breathable O2 for the crew.

For the Phobos Base Architecture, UVM proposed automated assembly, with a fairly simple configuration based upon the TransHab-derived Bigelow Aerospace "Olympus" inflatable module. In addition to this single very large pressurized environment, the UVM Phobos Base would incorporate an observation tower and foundation hub/berthing module. FIGURES 10 and 11 show the base configuration and the cross section through the Olympus module side by side.

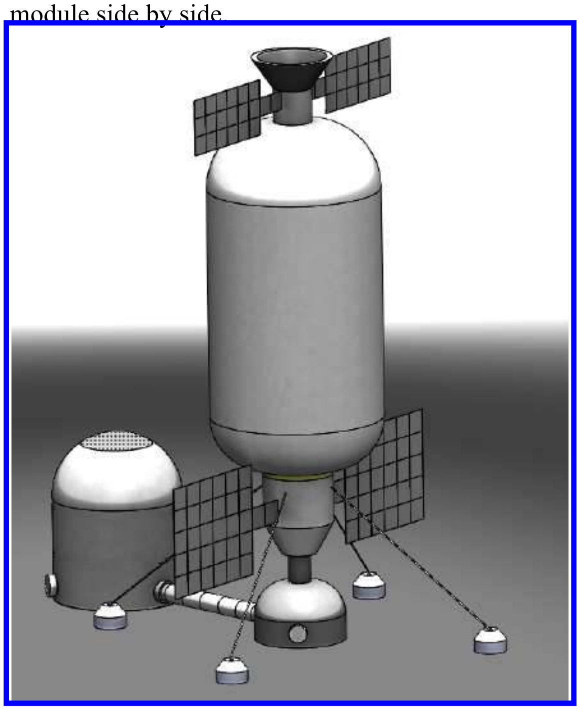


FIGURE 10. View of the UVM Phobos Base, showing the Olympus Module, Observation Tower and docking node.

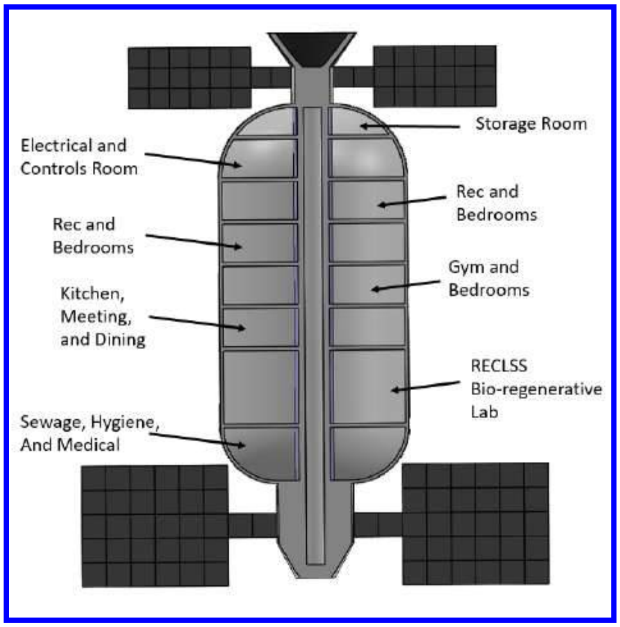


FIGURE 11. Transverse section of the UVM Olympus inflatable module, designating the various functional volumes.

Although as the UVM engineering work showed originality, sophistication, and subtlety, their architectural design and drawings appear very simple, and in some aspects simplistic. This contradiction suggests that the UVM team consisted predominately or entirely of engineers, with few if any architects. The floor plan for "Module 1" the berthing module that the UVM configuration would anchor to the Phobos surface provides an example of outward simplicity in the rendering but with some reasoning behind it.

FIGURE 12 presents the floor plan of this foundational *Module 1*. FIGURE 12 shows Module 1 providing three radial ports penetrating the pressure vessel wall. These radial ports can accommodate berthing connections such as the tunnel to the Observation Tower, and EVA airlock, or docking to a pressurized spacecraft. The UVM design logic makes this module both a science laboratory for Astrobiology and a workshop for fabricating whatever the crew may need to make or replace on Phobos. It appears to include a separation wall between these two key functions. In the UVM scheme, the anchorage of *Module 1* to the solids below the Phobos surface forms a critical part of the Phobos Base structure.

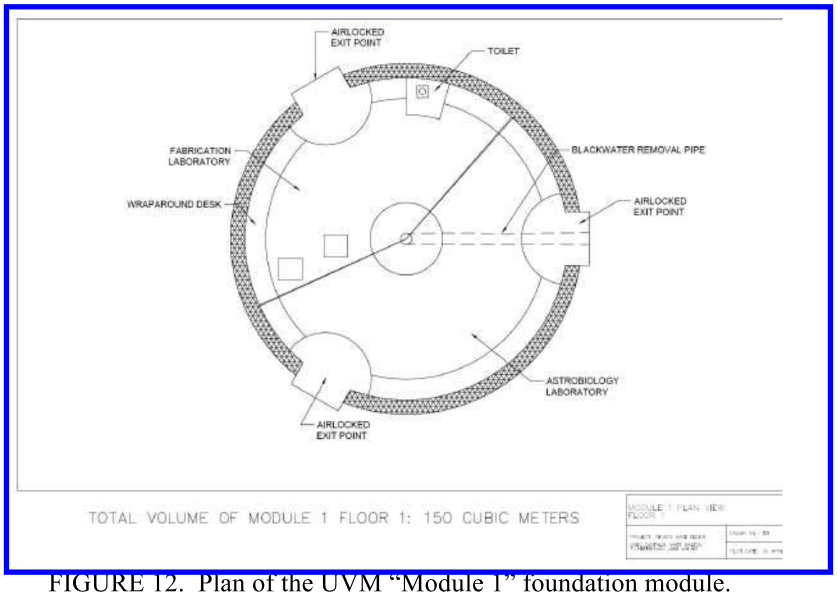


FIGURE 12. Plan of the UVM "Module 1" foundation module.

B. Wroclaw University of Technology

The Wroclaw University team brought a wide range of capabilities to the Phobos Base design problem. They named their project *Phobos Base Fearless,* negating or refuting the name of Phobos, which means *fear* in Greek. So, here it shall be *Base Fearless.* Their capabilities appear to include structural and mechanical design engineering. The students produced results in structural and architectural engineering; they designed a cable-restrained holding the atmospheric pressure over a foundation. One key element of the Wroclaw concept is a fission reactor, for which they performed detailed calculations.

FIGURE 13 shows an overview rendering of the complete Wroclaw *Base Fearless*. The cable-restrained roof of the inflatable stands out as the central architectural feature. In addition, there are a variety of smaller outlying utility structures and subsystems. At a smaller scale there appears a wealth of subsystems.

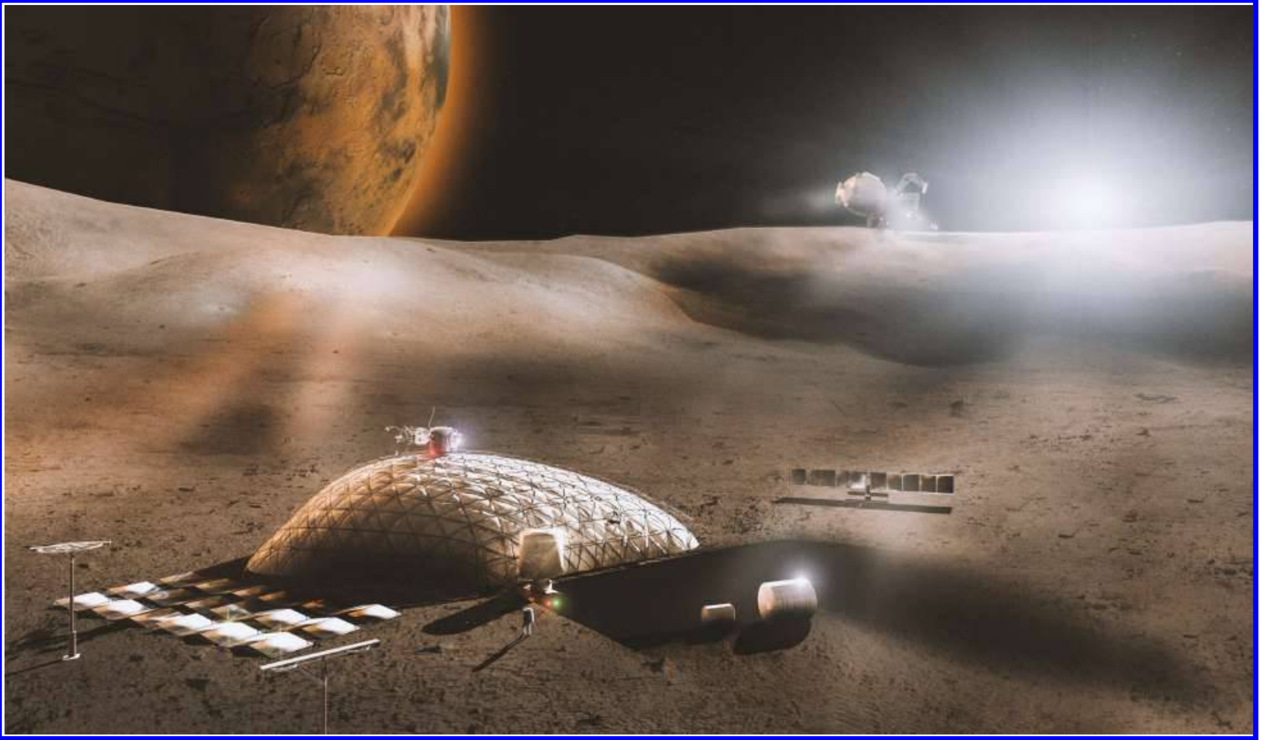


FIGURE 13. Wroclaw University concept for Phobos *Base Fearless.*

FIGURE 14 shows a detailed structural cross-section of the cable-restrained inflatable roof. Although the students did a credible job on how the tension cables would help restrain the roof fabric and maintain its shape, they are nearly silent on how to attach the roof in a leak-proof manner to the foundation. What they say is:

> Construction is attached to the ground using prefabricated carbon fiber elements anchored to the ground by meter long steel screws. Cushions are connected to plate using “zipper” technology.

That roof to foundation connection will prove critical to maintain the integrity of the atmosphere containment, and it is unlikely that the arrangement in this brief description would be sufficient. Since this roof covers the largest pressurized volume, the ability to secure it in a pneumatically sealed manner will prove critical to protecting the health, safety and lives of the crew.

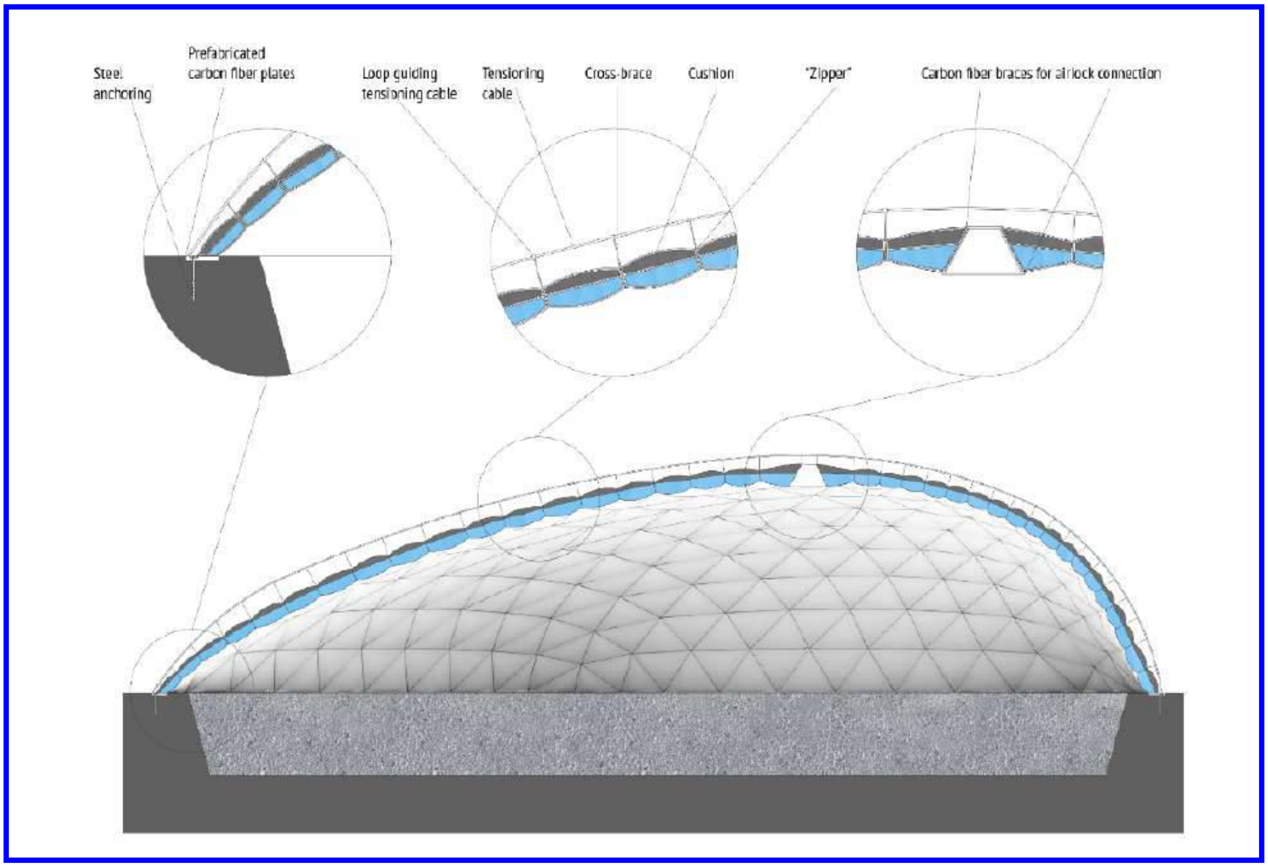
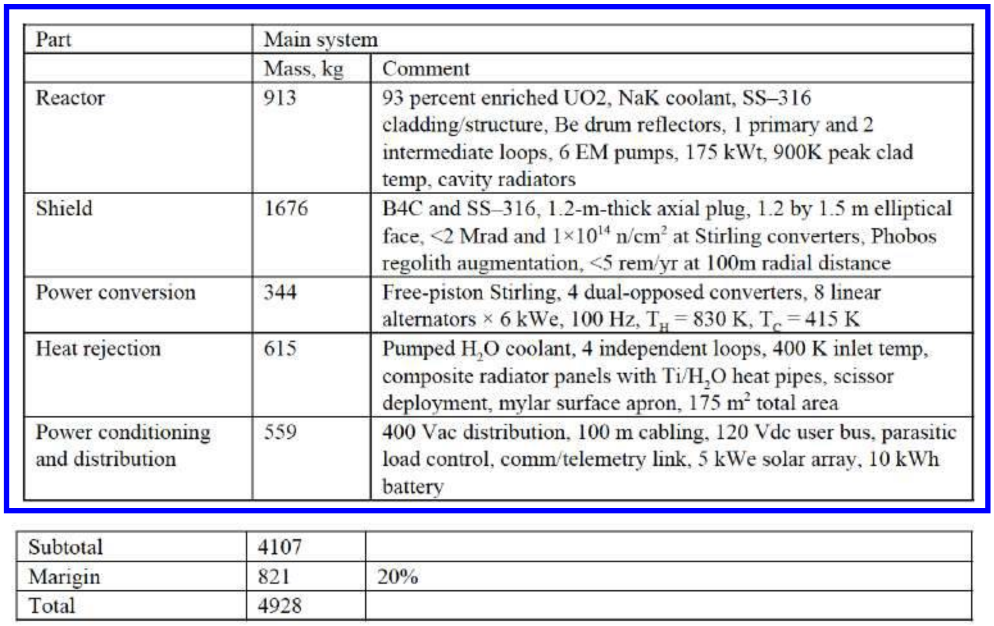


FIGURE 14. Structural cross-section of the Wroclaw University inflatable, cable-restrained roof.

The students went into considerable detail on the design of the fission reactor and the mass of its constituent elements. FIGURE 15 shows their mass table with elaborate comments about the constituent parts.



Part	Main system	
	Mass, kg	Comment
Reactor	913	93 percent enriched UO2, NaK coolant, SS–316 cladding/structure, Be drum reflectors, 1 primary and 2 intermediate loops, 6 EM pumps, 175 kWt, 900K peak clad temp, cavity radiators
Shield	1676	B4C and SS–316, 1.2-m-thick axial plug, 1.2 by 1.5 m elliptical face, <2 Mrad and 1×10^{14} n/cm^2 at Stirling converters, Phobos regolith augmentation, <5 rem/yr at 100m radial distance
Power conversion	344	Free-piston Stirling, 4 dual-opposed converters, 8 linear alternators × 6 kWe, 100 Hz, T_H = 830 K, T_C = 415 K
Heat rejection	615	Pumped H_2O coolant, 4 independent loops, 400 K inlet temp, composite radiator panels with Ti/H_2O heat pipes, scissor deployment, mylar surface apron, 175 m^2 total area
Power conditioning and distribution	559	400 Vac distribution, 100 m cabling, 120 Vdc user bus, parasitic load control, comm/telemetry link, 5 kWe solar array, 10 kWh battery
Subtotal	4107	
Marigin	821	20%
Total	4928	

FIGURE 15. Table of masses of the components of the Fission Power System

Towards the end of the *Base Fearless* report, the students pull together all the diverse elements into one site plan/axonometric that goes a long way to explain their concept. They separate three major activity areas: the Mining Site coupled with the Nuclear Power Station, the Mars Observatory, and finally, the *Base Fearless* core itself. It makes good sense to locate the mining site close to the nuclear fission reactor because mining will surely consume more power than any other part of the base. Separating the Mars Observatory some distance away from the activities at *Base Fearless* would help in minimizing contamination from dust kicked up or propulsive gases released in the vicinity of the base core and the mining site. This base core proves more complex and lively than FIGURES 13 and 14 may suggest.

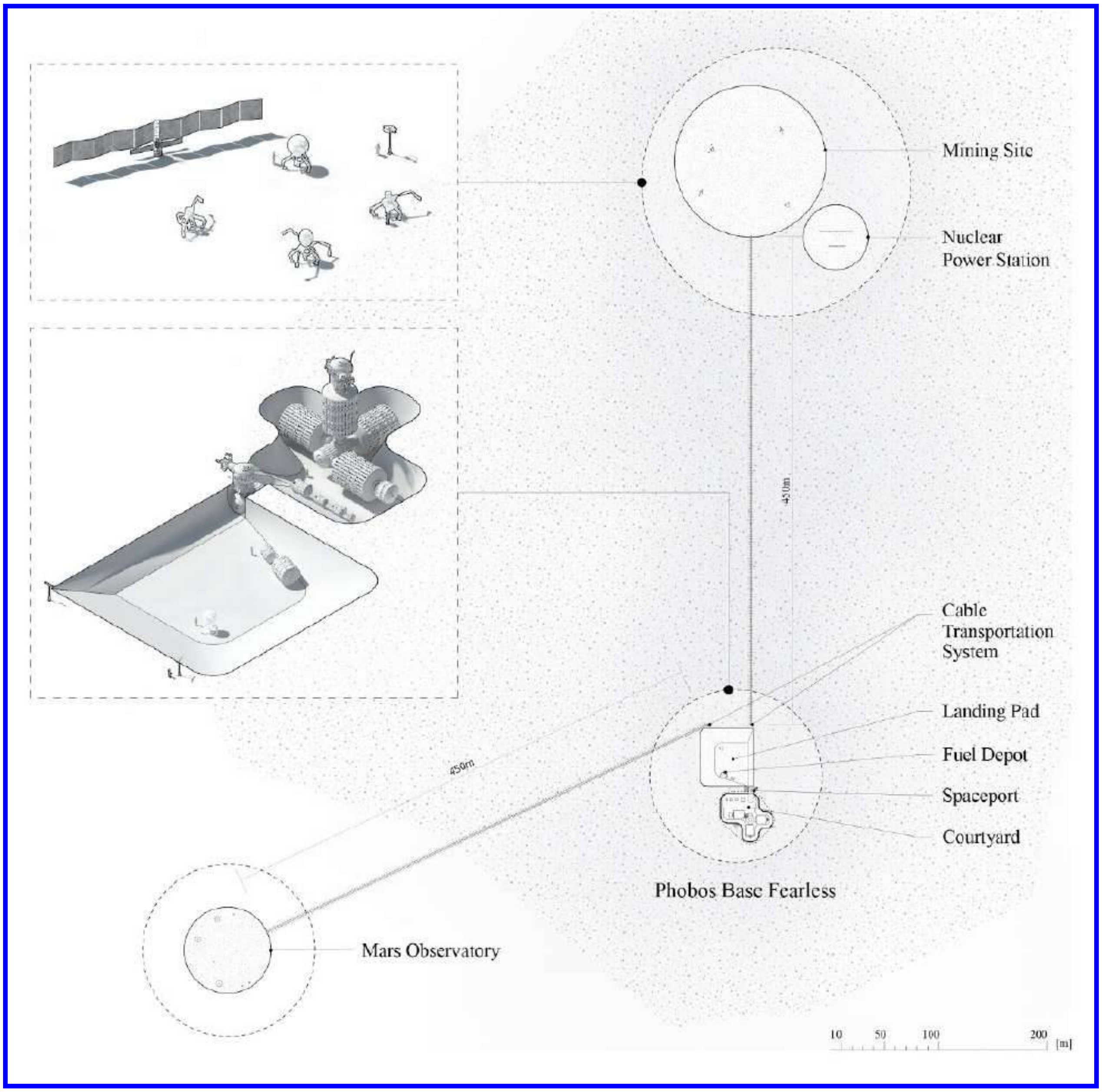


FIGURE 16. Wroclaw University Phobos *Base Fearless* plan and axonometric.

In the two frames on the left appear axonometric views of parts of the *Base Fearless* concept. The upper frame shows a radiator system to cool the fission reactor. In front of it are several versions of the *Base Fearless* lander and utility vehicles. Some of these vehicles are equipped with drills, some with robotic arms, some with other tools. The ones with the spherical bubbles can serve as pressurized spacecraft in their own right. In the lower frame appears the excavation for the “basement” or lower volume. This rectangular area with the sloping sides area is not pressurized; it accommodates the landing pad, which would be made of sintered regolith or otherwise compacted and solidified. Connecting to this volume sits a passage or tunnel leading to three cylindrical modules. These three modules presumably provide the main living and working areas for the crew at *Base Fearless*, covered by the cable restrained inflatable roof.

This site plan conveys both careful thought and a contradiction. The students took great cares to move the nuclear reactor and the Mars observatory far from the *Base Fearless* core. However, they located the greatest threat to safety, the landing pad where a fuel-laden propulsive vehicle will touch down, only a few meters from the living quarters for the crew. A misguided descent or a bad landing could cause an impact and an explosion, wiping out everyone in these nearby modules. That would be something to fear. Never the less, the students did an admirable job in putting together the most complete and sophisticated site plan in the competition.

IV. Discussion

This discussion and the lessons learned that follow deal primarily with the issues of organizing and operating the student design competition. Ideally, this operation should be completely invisible to the students. They should need to deal only with the design brief and the competition rules. To a very great extent, that was how this competition transpired. However, to prepare to hold another competition and a better one, it is vital to discuss the issues that arose for the TCs that organized this student design competition.

The team from the AIAA LSSTC and SATC commenced discussions about holding a joint student design competition in the Human Spaceflight category at the 45th International Conference on Environmental Systems (ICES) in Bellevue, WA in July of 2015. Shortly thereafter, the Joint TC Team produced the first draft of the design brief. This Joint Team went through many revisions. When the team felt the draft was ready, they presented it to the staff of the AIAA Foundation that organizes and runs multiple student design competitions each year.

However, the AIAA Foundation staff had just undergone a reorganization that cast into doubt the schedule for when they would review the proposals from the Technical Committees to select the design competition proposals for the 2017 competition year. Not surprisingly, seen in hindsight, there was a considerable amount of confusion concerning what the competition proposal needed to say, what were the criteria for selection, and the extent to which these criteria may have changed from previous years.

Early in the process of communicating and coordinating with the AIAA Foundation, it became clear that it would be necessary to name one of the TCs as the lead organizing entity and to name a single point of contact. Since Donna Rodman was the only person who volunteered to be the point of contact with the AIAA Foundation and she belonged to the LSSTC, ***that*** settled it. Donna spoke at length to the staff and attempted to interpret for the Joint TC Team what the staff told her. However, that interpretation was difficult because it consisted of literally "playing telephone." Donna would talk to the staff, and then she would write in an email what she thought she heard them recite from their documents. Finally, the Joint TC Team was able to elicit from the staff the written competition proposal template. From that time, it was possible to move ahead with composing the competition proposal to meet the criteria and rules of the AIAA Foundation.

The two TCs agreed that ideally the design competition should consist in equal weight of Life Support Engineering and Life Science Countermeasures on one hand and Space Architecture, habitability and the design of space living and working environments on the other. The teams completed and agreed upon the competition proposal and submitted it to the AIAA Foundation. A paper at the 46th ICES in 2016 reported on this progress (Cohen, 2016). The AIAA Foundation selected the Phobos Base proposal from the Joint TC Team in the summer of 2016. They said it was their turn to carry the ball; we could relax and let them do the rest.

The AIAA Foundation staff packaged the Phobos Base design brief into their RFP format that went out via email to all the AIAA student chapters. It also appeared on the AIAA Foundation website along with other design competition RFPs such as aircraft design. One of the incentives the AIAA Foundation provides is a prize: $500 for first place, $250 for second place, and $100 for third place. However, for reasons unknown, the advertisement for the Phobos Base competition did not mention the prizes. So, it looked to would-be student teams like it was the only student design competition lacking the endowment of prize money. The Joint TC Team did not discover this omission until long after it was too late for adding the prize money to make any difference.

As a consequence, other student design competitions received up to 15 entries. The Phobos Base competition received only four valid entries; these were the four that won places in the design competition. The Phobos Base design competition received one more entry from the University of Southern California that consisted largely of a polemic about why putting a human base on Phobos was a mistake. The judges ruled that because this submission did not actually include a design project it was non-responsive and therefore they could not evaluate it.

A further complication arose for the 2017 ICES when the Joint TC Team wanted to reserve presentation time slots for the winning teams to present their work at the conference. The ICES Steering Committee did not vote to approve such an arrangement. The conference chair for that year insisted that only papers that passed successfully through the standard abstract approval and manuscript approval process could be published or presented. The only alternative would seem to be to invite the winning student teams to submit an abstract by December and then come back the next July to present their work of a year earlier.

The entire design competition design cycle took two years, from the beginning of the idea in 2015 to the announcement of the competition in September 2016, to the receipt of entries in April 2017, judging, and announcement of winners in June 2017. The Joint TC Team's plan had been to award the prizes at the 2017 ICES. However, that was far too short notice to allow the teams—especially the ones from Nepal and Poland—to travel to the USA by mid-July.

A final, unexpected problem was that the Joint TC Team was unable to obtain the judges' written evaluations and comments about the design submissions. The judges entered their comments on the competition and registered their scores in an online format that the AIAA Foundation operates. It would have been very helpful to the Joint TCs to review the judges scores to understand how well the students rose to the competition challenge in the judges' estimation.

V. Lessons Learned

So here are the lessons learned:

1) If anyone refers to a document, a guideline, or a template, make sure to get it in written form as soon as possible. Do not try to rely upon a recitation of a text over the telephone.

2) Stay in active communication with the AIAA Foundation Staff throughout the process, even when they seem to say, "Please stop bugging us, we will take it from here."

3) Pick a single point of contact to communicate with the AIAA Foundation and provide a lot of back up, including having multiple members of the TC team participating in telecons.

4) Check all the correspondence carefully and follow all the links to make sure everything is happening the way it should.

5) Make the effort to advertise the design competition outside of AIAA channels to students at universities that work with the TC members where there may be AIAA student chapters.

6) Use a system for uniform location of content so that it is easy for the judges to compare the submissions "apples to apples" and find all the teams apples.

7) Make sure that the judging evaluation criteria are clear and that the volunteer judges follow it. The AIAA Foundation uses some standard criteria, but it is important to make sure that the overall evaluation addresses the key points of the design brief.

8) Schedule the award ceremonies long enough after the judges complete their work and the winners receive notifications that they can plan travel to the award ceremony and raise money to fund it. In this instance, the next AIAA meeting, the Space Forum and Exposition, typically held in September, may provide the best option.

9) Arrange in advance with the AIAA Foundation staff that they will furnish the final evaluations and scoring of the student design submissions to the sponsoring TC(s).

10) Pick a conference to present the prizes to the winners where it is possible to create placeholder abstracts in a student paper track for the winners of the design competition to submit their cleaned-up reports as conference papers, thereby making them formally referenceable.

VI. Conclusion

The AIAA Phobos Base Student Design Competition was a worthwhile endeavor. The student teams did a terrific job in their design submissions for Phobos Base. The competition proved as much a challenge to the Joint TC Team as first-time design competition organizers as it did to the students.

Team design competitions of this type can afford a very rich and meaningful design experience for the students. Perhaps the most important factor for them is to start the competition early, during the fall quarter or semester. For that reason, it is important to get the word out to prospective student teams as early as possible. Ideally, the student teams will work on their design submissions for two quarters or two semesters instead of coming to the competition RFP late in their second term.

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References

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