Human Performance Considerations for a Mars Mission

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Abstract—As humans contemplate further exploration of our universe, many questions arise regarding the implications of these new endeavors, many of which have yet to be fully addressed.

Scientists have long wondered whether the human body is suited for spaceflight. The original issue was whether humans could merely survive even a short flight into space, let alone remain healthy during a long trip.

Spaceflight produces a plethora of physiological and psychological effects in humans, which range in time of onset, duration, and recovery from minutes to months. Some of the most serious effects are cardiovascular deconditioning, bone demineralization, and radiation damage.

A crucial concern to be addressed in preparing for extended human spaceflight missions is how to keep the crew healthy and safe during all phases of the mission, as well as upon their reintroduction to earth's environment.

Over the past four decades of spaceflight, the collected assortment of varied measurements on the small number of animals and humans that have actually experienced long-duration spaceflight, together with the data from various studies in simulated microgravity, are uncertain predictors of what exactly might take place physiologically during the sequential phases of an extended planetary mission.

If astronauts are expected to perform at peak levels on the Martian surface after 5 months of interplanetary travel, and resume normal, active lifestyles upon their return to earth after a total of 31 months of space exploration, a serious effort must be made toward keeping them healthy during each phase. Bone loss is one of the most difficult problems to prevent and recover from. The musculature and cardiovascular systems are significantly more resilient.

Physiological and psychological effects and countermeasures are discussed. Crew capabilities and limitations are considered. Human factors design recommendations are listed. Crew volume estimates are addressed.[1,2]

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1. INTRODUCTION

As humankind contemplates ever further exploration of our universe, and the notion of interplanetary travel evolves from fiction to fact, many questions come to mind regarding the implications of these new endeavors. Where will we go? How far can we expect to travel? How long will it take? What will we find? Will our bodies remain healthy? Is human space travel a worthy goal to spend time, money, and energy on? These and many other questions have yet to be fully addressed.

Background

From the very beginning of our ventures into space, scientists and physicians have wondered whether the human body is suited for spaceflight. The original issue was whether humans could merely survive even a short flight into space, let alone remain healthy during a long trip. Because of this fundamental concern, both the Russians and the Americans first sent animals (primarily dogs and apes) into space prior to sending humans. When most of the animals returned alive and without any major health problems, both countries proceeded with sending humans on very short trips. Yuri Gagarin of the Soviet Union was the very first human space traveler, and Alan Shepard was the first American in space.

The unique conditions of spaceflight - such as microgravity, high radiation levels, isolation and confinement, vibration, acceleration, and noise levels (especially during launch and re-entry), as well as the stress imposed by the hostile external vacuum and extreme temperature variations - produce a variety of physiological and psychological effects in humans. These effects manifest themselves throughout the body and mind, and range in time of onset, duration, and recovery from minutes to months. Some of the most serious

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effects are cardiovascular deconditioning, bone demineralization, and radiation damage.

Problem Statement

A crucial concern to be addressed in preparing for extended human spaceflight missions (such as a Mars conjunction class mission) is how to keep the crew healthy, safe, and as productive as possible during all phases of the mission (including the 5-month transit from earth to Mars, 20 months of surface time, and 6-month return trip to earth), as well as upon their reintroduction to earth's environment.

Human exposure to reduced gravity has been observed with interest over the past four decades of manned spaceflight, but the collected assortment of varied measurements on the small number of animals and humans that have actually experienced long-duration spaceflight, together with the data from various studies of animals and humans in simulated microgravity, are somewhat uncertain predictors of what exactly might take place physiologically during the sequential phases of an extended planetary mission.

This paper gives an overview of the human performance issues that must be addressed in planning and preparing for a successful human mission to Mars. Physiological and psychological effects and countermeasures are discussed, as well as crew capabilities and limitations. Human factors design recommendations are given, and crew working volume estimates are considered.

2. DISCUSSION

Physiological Effects

Residence in the "weightlessness" of space seems to affect human physiology in much the same way as extended inactivity such as that imposed by bed rest. Muscular atrophy, particularly of the large, lower body anti-gravity muscles, is common. Progressive bone loss, particularly in the legs, pelvic girdle, and spine, is observed which is similar to that seen in disuse osteoporosis. However, bone mineral losses on the Skylab mission were about four times greater than what was predicted by bed-rest studies [12]. Bone loss occurs even on short duration missions. Bone mineral losses appear to increase roughly in proportion to mission duration [22]. Both musculature atrophy and bone loss can be largely attributed to the removal of the mechanical forces produced by gravity on the weight-bearing structures of the body, while muscle strength recovers more quickly than bone strength.

Another physiological spaceflight phenomenon is the headward shift of bodily fluids, which creates increased pressure on the heart's aortic baroreceptors, which in turn suppress production of antidiuretic hormone. This chain of physiological responses results in an overall reduction in blood volume.

Cardiovascular deconditioning also occurs during prolonged spaceflight in response to the absence of gravity. The heart doesn't have to work as hard to pump blood in microgravity, and the total blood volume is decreased, so it gets smaller. The heart beat may also be altered.

Neurovestibular disorientation may be experienced early on in adapting to microgravity, and can cause Space Adaptation Syndrome (SAS) or other problems. Disturbance of normal sleep patterns is also common, which can have a dramatic effect on human performance. In addition, immunological problems may be encountered, making the body less resistant to disease and infection.

Furthermore, Russian investigators have suggested a two-phase metabolic response to the stress environment of spaceflight. The first phase is an increase in metabolism, and the second is a two-step decrease in metabolism to lower than the initial starting point [11]. Their study links the first phase increase in metabolic rate to a resultant increase in resorption of bone minerals into the blood, and the second phase decreases in metabolic rate to resultant abnormal tissue oxygenation and metabolic acidosis.

Radiation exposure limits for interplanetary missions have yet to be established. Increased radiation exposure (from galactic cosmic rays, solar particles, trapped belt radiation, or other ionized particles) outside the earth's protective atmosphere may manifest effects somatically in cellular damage or genetically in reproductive defects. Radiation exposure at the earth's surface is less than 0.6 percent of that received in low earth orbit (LEO), less than 0.3 percent of that received in transit to Mars, and 0.7 percent of that received on the surface of Mars. As would be expected, the highest radiation exposure levels will occur during the Earth-Mars interplanetary transit segments of the mission [14].

Other physiological effects may include electrolyte imbalance (due to bone demineralization and fluid loss), nasal congestion, reduced stimulation of taste and olfactory receptors, and desynchronosis, or disruption of circadian cycles.

Physiological Countermeasures

A major objective of both Russian and American space programs has been to minimize the time and energy devoted to physical conditioning and other countermeasures intended to ward off the cumulative adverse physiological effects of weightlessness, so that more spaceflight time can be freed up to perform useful space science or other productive work. The Russians have estimated the probability of an "in-flight medical event" occurring to be 1.4 per cosmonaut per year [10], so the development and implementation of effective preventative countermeasures is time well-spent. Similar studies of American astronauts indicate that the most likely medical problems to occur (such as skin disorders, injury/poisoning, and ear/nose/throat disease) would have the least impact on mission success. Conversely, the medical problems thought to have the greatest potential impact on mission success (such as cardiovascular, stomach, and bowel diseases) are the least likely to occur [5].

Numerous countermeasures have been tried both in spaceflight and in ground-based bed rest studies with varying rates of success. These include various exercise programs utilizing treadmills, bicycle ergometers, and bungee cords; body-loading devices such as lower body negative pressure suits and elastic strap suits; a variety of pharmaceutical agents, and finally, centrifugation of animals in space and humans on earth.

There are probably more unanswered questions in this field than there are answered ones, since relatively little scientific biomedical research on humans in actual (as opposed to simulated) microgravity has been performed. The experimental data that do exist have been collected under loosely controlled conditions, with inconsistencies in measuring techniques and test subject anomalies. In many cases, it is difficult to sort out which causes are responsible for which effects, as is the case when numerous exercises and other countermeasures have been used together over the course of a spaceflight mission, resulting in some net measurements of various fitness indicators.

Because spaceflight is so expensive and human health is at stake, the general approach to spaceflight physiological problems has (for good reasons) been less concerned with understanding the fundamental nature of the problems than with making them go away. While this approach has sufficed for near-earth short-duration flights, the hope for interplanetary travel in the not-too-distant future necessitates that more attention be paid to understanding how to effectively and efficiently deal with these problems during possible three-year roundtrips to Mars or other destinations millions of miles from earth.

As mentioned previously, numerous physiological countermeasures to spaceflight have been implemented with varying rates of efficacy [6]. The Russians have claimed that through their programs of exercise and the use of body-loading devices, they have been able to limit weight-bearing bone mineral losses to about seven percent during six-month flight periods, and keep their cosmonauts healthy enough to remain productive during that timeframe.

Certain exercise regimes seem to be more effective than others in achieving overall fitness goals, while other regimes service one area of fitness and exacerbate another. For example, high-contact-force treadmill running appears to be more effective for cardiovascular conditioning, bone maintenance, and musculature conditioning than is vigorous cycling, which may actually increase bone mineral resorption into the bloodstream while exercising the heart and muscles. Current research suggests that increasing ground reaction forces on the foot (which would be transmitted in turn to the leg) has a much greater influence on bone density than does increasing the walking or running time [4][19]. Resistance training devices currently under development in conjunction with the International Space Station program hold some promise for ameliorating several of these problems.

Various body-loading devices may quite possibly have some value in imparting gravity-like forces to the body, and in so doing, stimulate physiological responses helpful to muscular, cardiovascular, and skeletal fitness. The challenge of implementing such devices is in making them comfortable enough to be willingly used by astronauts on a regular basis.

Figure 1: A test subject participating in a Mars-gravity simulation at NASA Ames Research Center exercises with a backpack load configured to emulate a proposed life support system [21].

Several drugs have been shown to be effective in controlling bone mineral losses primarily through decreasing resorption in human bed-rest or restrained-animal studies for extended periods of time, but due to possible differences in spaceflight bone loss mechanisms, they may or may not be effective in controlling bone loss during spaceflight [22]. Nevertheless, some of the more promising pharmaceutical agents should be investigated further. Growth hormone and growth hormone potentiators may also prove to be beneficial.

Centrifugation, or “artificial gravity”, has been suggested as a possible remedy for all of the physiological woes associated with spaceflight, but so far it seems to be a fantastic idea lacking a means of effective implementation. The large scale centrifuge concept made popular by the movie version of 2001: A Space Odyssey would be extremely expensive to launch and/or build in space, but would indeed solve most of the physiological problems identified here. The major problem associated with a small radius, high rotational velocity centrifuge would be the very perceptible “gravity gradient” effect, caused by different levels of acceleration at different parts of the body (note that centrifugal acceleration equals tangential velocity squared divided by radius of rotation). This would cause blood pooling in the lower extremities, as well as vestibular and visual confusion, very likely leading to motion sickness and other medical problems.

An alternative method to achieve long-radius centrifugation would be to attach a habitat module to a counter-mass with a long tether that could be spooled out after achieving orbit, and rotate the whole system about the center of mass. If centrifugation is used, it should be at a level equivalent to earth’s surface gravity in order to maintain bone mass. Otherwise, exercising astronauts must add body-loading weights to their exercise regime in order to achieve the ground reaction forces and compression loads required to stimulate adequate bone regeneration (as they should do while exercising on the Martian surface).

Radiation exposure may be mitigated through the use of shielding materials in transit vehicles and surface habitats, and to a lesser extent in spacesuits. Radioprotectant ingestible substances may also be useful. Antibiotics may be used to treat or prevent infections when radiation exposure has compromised a patient’s immune system. In extreme cases of lethal doses of radiation exposure, bone marrow transplants have been shown to improve patients’ chances of survival.

Desynchronosis can be minimized for earth orbital missions by synchronizing crew schedules with ground control schedules.

Psychological Effects

Compared to concern for the astronaut’s physical safety, little consideration has been given to the psychological impacts and adjustments associated with spaceflight. Yet as we prepare for longer, more complex, more distant space travel the full spectrum of human psychological and social requirements must be seriously addressed.

Some kinds of psychological effects are to be expected on any remote mission, especially one of extended duration and in confined quarters. On submarine missions, evacuations for psychiatric disturbances rank just behind evacuations for trauma and surgery.

Most of the following factors are found in remote habitats; some are more specific to spaceflight. Some factors are territorial issues; some are sensory stimulation issues:

- Isolation
- Confinement
- Limited habitation volume
- Compromised quality/conditions of habitation environment
- Absence of fresh air
- Reduced sensory stimulation
- Boredom
- Regimented work/rest schedules
- Strangeness of environment
- Awareness of risk

Each factor can contribute to mood disturbances, impaired intellectual function, problems with work, interpersonal conflicts, loss of sleep, apathy, depression, and withdrawal. If interpersonal conflicts or work problems lead to withdrawal or feelings of being outcast by the group, being an exiled member of an isolated group can be very traumatic, and can lead to more serious semi-psychotic indications such as hallucinations, crying, loss of appetite, silence, paranoia, and lethargy.

Some behavioral research suggests that remote mission adaptation progresses through several distinct sequential phases [1][2]. The first phase might last for 60 days or more, and may be characterized as a high motivation period of adjustment to a new and exciting environment, with the crew adapting an “us” (crewmembers) and “them” (non-crewmembers) mentality. The next phase might last from about the 60 day mark to the mission midpoint, characterized by a loss of energy, error-prone performance, and psychosomatic illnesses. Sometime during this phase the “us versus them” evolves into a “me versus the rest of you” mentality. The third phase would last from mission midpoint through third quarter, characterized by apathy, withdrawal, depression, and declining productivity. The final phase would extend from the third quarter through the end of the mission, and would be considered the "home stretch", characterized by renewed motivation, increased energy, improved productivity, and enhanced mood.

Psychological Countermeasures

Due to the unpredictable nature of psychological crises, a little effort expended on prevention is far preferable to the great amount more that would otherwise be required for management or treatment. The list of recommendations below represents a variety of measures that can be implemented to prevent psychological problems from occurring.

- Vehicle/habitat design: should be as earth-like as possible: local vertical; earth scenes on video and art; artificial gravity if practical; allow for privacy, personal touches and reminders of home.
- Mission/work design: give crewmembers a sense of control of their own work, schedules, decisions, or at least some input into decisions affecting them; allow creative use of free time.
- In-flight ground support: provide frequent two-way communication with support network of professionals, friends and family.
- Crew selection and composition: select mature, stable astronauts, with self-awareness and sensitivity to potential problems; crew mix must consider personality attributes and group dynamics.
- Crew training: train crew in team social dynamics, enabling them to handle problems as they arise; instill realistic expectations; view spaceflight as a lifestyle, not an endurance race to be survived.
- Psychotherapy: encourage psychological assessment on a regular basis with professional assistance.
- Designated on-board counselor: assign a counselor who is respectable and respectful, empathetic, understanding, consistent, and unconditionally caring.
- Awareness training: train in relaxation, meditation, biofeedback and autogenic techniques to help with sleep, reduce anxiety, increase calmness, focus attention, decrease stress, increase awareness.
- Regular physical fitness training sessions: exercise to increase energy and reduce stress.

If a psychological "event" does occur, treatment and/or management possibilities would include pharmaceuticals, crisis intervention, psychiatric evaluation and therapy, restraint and/or quarantine. In the case of a Mars conjunction class mission, evacuation is probably not a feasible option.

Human Factors Design Considerations

Crew safety must always be the top priority in any human space mission. The crew is already operating under tenuous conditions, and should never be intentionally placed in harm's way. Mission planners and designers should work together to protect the crew from all potential electrical, thermal, pyrotechnic, radioactive, chemical, mechanical, and pressure hazards. All structural corners, edges, and protrusions must be rounded and de-burred; all snag hazards must be eliminated.

The next human factors design priority is the provision of adequate volume and any other requirements for the full anthropometric size range of crew body and hand (pressure-suited, if EVA), visual and tool access, along with full ranges of motion within the optimum work envelope (easy arm/hand reach at chest height). If the crew is unable to access the site or the interfaces, the task simply will not get done.

Astronaut-friendly design implies designing well within crew capabilities and constraints. Task demands should be limited relative to strength, stamina, agility, dexterity and simultaneous actions. Interfaces should be designed to be actuated with one hand and with minimal tools. Interfaces should be standardized in order to minimize requirements for unique tools and training. Alignment aids and capture features should be implemented for assembly or replacement equipment wherever practical. Crew stability and mobility aids must be provided as necessary to accomplish tasks.

Realistic task timelines should be developed based on human simulations, with extra time added for contingencies. Unexpected problems or delays can very quickly obliterate a timeline schedule.

Have back-up plans for every operation. For example, in case of problems or equipment failures, determine how each task could be accomplished with one crewmember rather than two, or using manual instead of power tools. Also, all flight tools and equipment must be fit-checked with flight hardware.

The following account summarizes the primary human factors design considerations for any space mission.

- Prioritize first crew then equipment safety
- Ensure accessibility to worksite and interfaces; physically, visually, and with tools

- Implement “user-friendly” design; make it fool-proof
- Accommodate reduced gravity neutral body positions
- Design for full anthropometric crew size ranges
- Design EVA tasks to be performed within spacesuit mobility ranges
- Design tasks to be performed within the crews’ optimum work volume (chest area)
- Consider reach envelope limitations
- Consider crew force application capabilities for each working environment (microgravity versus planetary gravity)
- Map out realistic task timelines
- Identify and protect against potential hazards
- Provide integral structural crew aids wherever practical
- Provide crew stability/mobility aids as necessary
- Strategize support equipment and tool requirements and logistics
- Provide replacement equipment alignment/capture aids
- Provide standard, captive fasteners
- Use wing-tabbed connectors
- Implement adequate lighting provisions
- Use easily identifiable labels and color-coding
- Be aware of and accommodate for EVA/IVA work constraints
- Always have backup plans/procedures

For Mars surface operations, partial gravity human biomechanics must be considered (Mars surface gravitational acceleration is 37.5% of earth’s). Locomotion stride length is likely to be longer, and forward body lean is likely to be increased. Other partial gravity biomechanics issues, such as balance, posture, force-imparting capability, c.g./load placement, and mobility, have significant influences on work performance, and are pecifically relevant to the design of various space hardware items, including vehicles, habitats, pressure suits, crew tools and support equipment. Depending on individual degree of physical fitness, force imparting capability is likely to be greater than it would be in microgravity, but less than it would be on earth, due to the reduction in leveraging capabilities correlated with decreasing gravity levels [21].

Another important consideration is the fact the crew may very well arrive at the Martian surface in a partially deconditioned state. Considering the range of possible conditions of the earth-to-Mars transit portion of the mission, potential adaptive alterations in some physiological systems may affect the function of other systems. For example, neurovestibular changes involving posture, locomotion, and autonomic function may alter the cardiovascular or muscular responses, leading to orthostatic intolerance or loss of muscle strength. We need to better understand how post-landing alterations in multiple systems may result in performance decrements or increased risk of injury, and to identify preventative or rehabilitation strategies for facilitating post-landing recovery of function and performance.

Transit Vehicle & Surface Habitat Volume Considerations

Transit vehicle and surface habitat design must be designed to accommodate the full anthropometric range of potential female and male crewmembers performing routine, contingency, and emergency operations in each of the domains that follow.

Paragon Space Development Corporation performed an activities-based anthropometric crew volume analysis for a range of spaceflight mission scenarios and durations, which culminated in the development of a Crew Volume Estimating Tool [20]. The estimates below were derived from this analysis.

Command/Control Area:

Flight deck, communications, navigation, power, thermal, etc.

Estimated volume per simultaneous use crewmember:

1.1 cubic meters

Payload/Science Area:

Experiment / payload interaction, monitoring, measurements, etc.

EVA facilities and equipment: suits, PLSSs, support equipment, and airlock.

Estimated volume (sized for 2 simultaneous EVA crewmembers):

5 cubic meters

Kitchen/Galley/Wardroom:

Meals, group gatherings; food and water storage; refrigeration; food preparation tools; dishes; microwave oven; garbage management; clean up provisions; audio/visual equipment, etc.

Laundry: clean and soiled clothing storage; laundry equipment; laundry consumables.

Estimated volume per simultaneous use crewmember:

1.5 cubic meters

Private Hygiene Area:

Privacy panels, personal lockers.

Toilet/hygiene facilities: commode; mirror; cosmetic care: shaving; grooming; face, hand, and hair washing; oral hygiene; clothing don/doff; solid/liquid waste management system, etc.

Shower facilities: full body showers on Mars surface (perhaps full body sponge baths in transit).

Estimated volume per simultaneous use crewmember:

2.5 cubic meters

Sleeping/Passive Activity Area:

Board, bag, restraints, eyeshades, earmuffs, headphones, video, etc.

Estimated volume per simultaneous use crewmember:

1.2 cubic meters

Exercise Area and Equipment:

Treadmill, exercycles, resistive training devices, loading devices (on surface), games, etc.

Estimated volume per simultaneous use crewmember:

3 cubic meters

Health Maintenance/Medical Facilities and Equipment:

Physical exams, tests, measurements; diagnostic equipment, first aid kit, respirator, defibrillator, pharmaceuticals

Estimated volume per simultaneous use crewmember:

1.1 cubic meters

Table 1 below summarizes the per-crew volume allowances for each functional area. If some functional areas can be "nested", or co-located, overall volumes may be less than that which would be derived by simply multiplying the number of "simultaneous use crewmembers" times the "estimated volume per simultaneous use crewmember", and adding the products for each functional area together.

FUNCTION	***m^3 per crew***
Command/Control	*1.1*
Payload/Science	*2.5*
Kitchen/Wardroom	*1.5*
Private Hygiene	*2.5*
Sleeping Quarters	*1.2*
Exercise Area	*3*
Health/Medical Area	*1.1*

Table 1: Summary of per-crew volume allowances for functional areas.

3. SUMMARY AND CONCLUSIONS

A number of very important questions still remain to be thoroughly researched and addressed as we plan for a human mission to Mars. Several of these are listed below.

- What is the best comprehensive physiological rehabilitation regime upon arrival at Mars?
- What is the best comprehensive rehabilitation regime upon return to Earth?
- What are the physiological predictors for selection of individuals most resistant to bone loss?
- What are the physiological predictors for selection of individuals most resistant to cardiovascular problems?
- What are the predictors for selection of individuals best psychologically suited to a long duration mission to Mars?
- Will bone mass loss continue indefinitely beyond the known range (e.g., for 31 months)?

- Can bone loss over long time periods (e.g., for 31 months) be recovered, and if so, how long does the recovery require?

- What are the best approaches to radiation shielding for humans during earth-Mars transit, Mars surface, and EVA work?

If astronauts are expected to perform at peak levels on the Martian surface after 5 months of interplanetary travel, and resume normal, active lifestyles upon their return to earth after a total of 31 months of space exploration, a serious effort must be made toward keeping them healthy during each phase. Bone loss is one of the most difficult problems to prevent and recover from. The musculature and cardiovascular systems are significantly more resilient.

Spacecraft designers and mission planners must consider crew capabilities and limitations based on physiological and psychological factors and conditioning levels in designing hardware and mission activities. Tasks should be simplified and human interfaces to hardware and software should be user-friendly. Crew health and safety must be the number one priority in planning, operations, and design. Life support requirements for all aspects of crew flight must be fully addressed in developing designs.

In conclusion, the following recommendations are offered:

- Select crewmembers that are most psychologically and physiologically suited to long duration spaceflight missions.

- Quarantine crewmembers for one week prior to mission.

- Limit outside contacts to close friends, family, and necessary professional contacts for one month prior to mission.

- Implement tethered habitat-countermass centrifugation at 1-g for transit out and back, coupled with in-flight exercise.

- During transit phases of mission, synchronize crew-time with ground control time.

- Allocate 8-hour sleep period for both in-transit and surface time schedules.

- Implement weighted exercise (using surface resources, such as sand, gravel, or stones in strap-on pouches) while on the Martian surface to emulate one-g load levels.

- Provide full-body showers in the surface habitat.

- Provide increased volume for exercise and recreation in the surface habitat.

- Consider implementing practical yet effective “creature comforts” to ease psychological and physiological stress, especially during the long stretch of time on the Martian surface.

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BIOGRAPHY

Leslie Wickman, Ph.D., *is currently director of the Center for Research in Science at Azusa Pacific University. She is an internationally respected research scientist and engineering consultant.*

For more than a decade, Wickman was an engineer for Lockheed Martin Missiles & Space in Sunnyvale, Calif., where she worked on NASA's Hubble Space Telescope and International Space Station Programs, receiving commendations from NASA for her contributions and being designated as Lockheed's Corporate Astronaut. For the last six years, she has worked as a research scientist with the RAND Corporation in Santa Monica on the technical and political aspects of various national defense issues. She also serves as a consulting scientist on fighter pilot training issues, future space launch vehicles, human factors problems for extreme environments, and runs a water reclamation research project.

As director of the Center for Research in Science at Azusa Pacific University, Wickman's responsibilities include addressing the relationship between science and theology. She has lectured extensively around the world on satellite servicing, astronaut operations, mission planning, and space physiology issues. She is also a dedicated athlete who plays competitive beach volleyball and women's professional tackle football.

Wickman holds a master's degree in aeronautical and astronautical engineering and a doctoral degree in human factors and biomechanics, both from Stanford University. She also graduated magna cum laude from Willamette University with a bachelor's degree in political science.