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Biomedical monitoring of spaceflight participants during suborbital flights via agile architecture

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As human spaceflight becomes a rapidly approaching reality, especially within the suborbital domain, measures must be implemented to monitor the mental and physiological well-being of vehicle operators and spaceflight participants (SFP). Vehicle operators remain better trained than SFP, this fact is amplified by the fact the cost prohibits majority of SFP to take multiple suborbital flights. Furthermore, current regulatory standards are insufficient to address SFP safety and medical standards. Due to the variations in commercial suborbital vehicle types, there will exist wide array of ascent and descent profiles. Even for a single vehicle type, the flight profile (i.e. climb angle, reentry trajectory, etc.) may vary flight-to-flight depending on the mission profile. Each commercial spaceflight enterprise may be constrained by multiple factors such as financial, vehicle design, vehicle-specific hardware, and other factors that limit the type of systems implemented. In light of the above, this paper shall propose adaptable system architecture for SFP biomedical monitoring that can be configured to multiple commercial suborbital vehicle types.

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Nomenclature

AST = FAA Office of Commercial Space Transportation
EVA = Extra-Vehicular Activities
FAA = Federal Aviation Administration
HTHL = Horizontal Takeoff and Horizontal Landing
HTVL = Horizontal Takeoff and Vertical Landing
G = G-forces
mHealth = mobile health
SFP = Spaceflight Participant
VTHL = Vertical Takeoff and Horizontal Landing
VTVL = Vertical Takeoff and Vertical Landing

I. Background

During launch, astronauts typically experience no more than 3.5g within orbital launch vehicles such as the Space Shuttle and the Soyuz [1, 2]. During descent, g-forces would not exceed over 4.5g for Soyuz or similar capsule design whereas the Space Shuttle experienced up to 3g [1]. Unlike orbital flights, commercial suborbital flight is likely to experience launch, ascent, and descent within relatively short amount of time. Thus, SFP are subjected dynamic g-forces in a short span of time with limited exposure to microgravity. Thus, unlike orbital flights, the greatest risk to SFP physiological and cognitive stability is dynamic flight profile resulting in variable g-forces [3]. Current FAA regulations do not require commercial spaceflight companies to train and instruct SFP to mitigate effects of high-g flights and the adverse states experienced therein. Neither doe the regulations require SFP to be trained within a high-fidelity environment where launch, ascent, and decent conditions can be realistically simulated.

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In the near-future the most probable suborbital flights will be horizontal take-off and horizontal landing (HTHL) and Vertical Takeoff and Vertical Landing (VTVL) [4] [5]. Within both flight profiles, positive G-force between 4g and 7g may be experienced by SFP during launch [6]. During launch, ascent, and landing, the g-forces would be experienced in the +Gz and +Gx axis [7]. The impact of high g-forces on SFP is a unique challenge due to the fact that SFP will have most probably limited training and exposure to hypergravity environment. Currently, the national aerospace training and research center, NASTAR, offers three separate courses for training in space flights and hypoxic conditions. Each course spans two days offering basics and an overview of spaceflight planning [8]. This also translates into limited training and countermeasures against hypergravity. Thus, the physiological affects experienced by pilots of high-performance aircraft would be further amplified on the SFP. Initial medical screening may help determine the level of fitness of individual SFP as well as aid in further training and mitigation against adverse physiologic states [9].

II. Physiological Effects of Short Duration Hypergravity Environment

Currently, the FAA, under Part 460, requires commercial spaceflight service providers inform SFP of the risks involved with spaceflight, sign a life waiver releasing the U.S. government of any responsibility, and train them for responding to emergencies. The requirements do not require commercial spaceflight service providers train SFP for micro and hypergravity environments nor train them for hypoxic conditions. Thus, the responsibility for SFP training falls independently upon the commercial spaceflight service providers.

The most direct impact of high G-forces, especially in +Gz and +Gx, can be readily experienced at the cardiovascular level. Tolerance of high G-forces is the ability to maintain sufficient blood flow to the head as well as maintain vision during both sudden G-onset as well as sustained G-forces. Depending on the rate of acceleration, the G-onset will vary; for slower acceleration, the cardiovascular system can adjust to the gradual G-onset thus delaying the onset of g-induced physiological effects. Even within a high G-onset situation, the physiological effects occur across a continuum. From disproportionate increase in weight and impact on the internal organs to cardiovascular changes that directly impact performance and cognition [7].

As the G-forces increase, the cardiovascular functions deteriorate due to increase in hydrostatic pressure. At +3Gz, the increased hydrostatic pressure begins to affect the vision, potentially leading to grey out; continued increase in G-forces (+4 Gz) could result in discomfort and grey/black out if no countermeasures are implemented. Of course there will be variations in the G tolerance of each SFP. The point at which SFP (or any individual) experiences black out can be considered their tolerance limitations. Beyond black out, there is a region of impairment termed Almost Loss of Consciousness (A-LOC), a rather nebulous region in the G continuum, A-LOC may cause mental impairment and loss if situational awareness without corresponding loss on consciousness. Beyond A-LOC is G-induced Loss of Consciousness (G-LOC). The onset of G-LOC can occur at and beyond +4.5Gz [7]. The HSF with SFPs on board should not get into situations where the SFPs are subject to blackout or even worse, the A-LOC. Values such as >+3Gx, +2Gz are unpleasant to general passenger and ideally should be avoided. Current technology though will require that the first SFPs may need to experience higher g-load due to the costs / market entry of technology and organizations that do not have precedence in the history of human space flight. Current regulations require commercial space transportation companies to train SFP to counter inflight emergencies such as '...emergency situations, including smoke, fire, loss of cabin pressure, and emergency exit.' [9]. At the moment, regulations do not explicitly require the well-being, safety and comfort of SFP, especially when taking into consideration the mental and physiological effects of hypergravity during spaceflight. When taking to consideration that highly trained operators such as fighter pilots will suffer from various mental and physiological effects of hypergravity, the effects become far more pronounced on SFP. Limited training and broad physical selection criteria for SFP may lead to cases of impairment, loss of situational awareness, medical emergencies, G-LOC, and host of other mental and physical adversities. Possessing the ability to monitor conditions of SFP via biomedical systems can greatly enhance the safety and well-being of SFP as well as enable commercial spaceflight companies to effectively maintain a SFP safety program to manage and respond to spaceflight-induced emergencies.

A. Disorientation

Rapid acceleration and onset of G-forces can affect the vestibular system causing illusions such as *oculogyral* or *oculogravic* [11]. Oculogyral illusion occurs when high acceleration is combined with rolling of the head. Objects can appear to have shifted from their actual position [11]. Oculogravic, due to high acceleration, can create the sensation of objects rising higher than they actually are [11]. While it is critical to ensure that vehicle operators are not affected by vestibular illusions for the sake of flight safety, vestibular illusions affecting SFP may cause disorientation, discomfort, potentially panic, and possibly induce other physiological conditions. Impact of

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vestibular illusions gains further importance when taking into consideration the current regulatory standards require commercial space companies to train SFP against emergency situations within the cabin [11]. Thus it is imperative to know the physiological and performant state of SFP.

It is worth noting that existing ground-based training technology is adding another level of complexity. The centrifuge facilities that are used for endurance and proprioceptive enhancement in hypergravity environments add another level by introducing the Coriolis effect that is relative to each motion performed by the trainee in the system. The potential SFP thus needs to be able to address even more confusing environment on Earth than during the HSF.

III. Physiological effects of Short Duration Microgravity Environment

The first suborbital flights provide the onboard crew and SFPs with seconds to few minutes of microgravity environment during the flight through the peak of the trajectory parabola. The rapid change of the environment can cause unexpected, emergent reactions of the SFPs.

The effects of microgravity on human body vary based on the duration of the exposure. Within the context of short-duration flights where exposure to microgravity is between seconds and few minutes, shift in tissue fluid and blood flow would be experienced [12]. Due to the impact of gravity on maintaining balance within the cardiovascular system and the compensation mechanisms by the body to adjust to gravity, microgravity will cause tissue fluid and arterial pressure to increase head ward. The blood volume within the heart nearly doubles leading to increased stroke volume. Observations made during real and simulated microgravity have indicated a 10% reduction in the left ventricular mass; though the causation remains either due to the reduction in myocardial workload or due to fluid exchanges [13]. Additionally, potential for cardiac arrhythmia exists given the disposition of individual SFP [13].

The current simulation environment of parabolic flight trajectories with Airbus or Boeing are commercially available and serve as a research lab or tourist attraction. The simulated hyper/microgravity flight profile could, to some extent introduce major difficulties of this variable gravity environment with particular emphasis on locomotion, proprioception and mental condition. Such flights can serve as a training foundation for ensuring SFP are sufficiently prepared against the physiological and mental stresses of the suborbital flights [9].

IV. Bio-monitoring

A. State of Art

One biomedical monitoring concept proposed by Hamilton et al. [6] a generic architecture composed of FDA-approved medical devices offered by companies such as Phillips, GE, and Welch Allyn. Clinically proven devices offer proven reliability and operational viability. Hamilton et al. [6] proposed a monitoring architecture measuring: pulse, blood pressure, electrocardiogram, oxygen saturation, respiration rate, and acceleration. The requirements included built-in storage capacity of minimum 3 hours, portable, noninvasive, recording bandwidth for ECG, and analog-to-digital. One limitation Hamilton et al. [6] faced was lack of operational data, specifications, and requirements of numerous commercial space operators.

Fei et al. [14] proposed a concept for NASA astronauts performing extra-vehicular activities (EVA) to monitor their physiologic state during operations. The concept was developed for EVA with configuration setup for astronaut monitoring. The biomarkers included heart rate, pulse ox, galvanic skin resistance sensor, and skin temperature sensor. Due to the difference in the operational environment proposed by Fei et al. and the one proposed in this paper (hypergravity), Fei et al. did not focus on impact of flight dynamics and flight regime on SFP. As such, this paper focuses on the impact of suborbital flight and related flight dynamics on SFP. Additionally, the paper proposes an agile and adaptable system that can be adapted to different type of suborbital vehicles.

NASA currently utilizes basic biomonitoring onboard the International Space Station (ISS) that include, "...rhythm monitoring via 12-lead wired electrocardiogram (ECG), semi-automated blood pressure assessment, and non-invasive blood oximetry via finger probe that measures oxygen saturation, carbon monoxide, methemoglobin, and perfusion index." [15] [16]. Antonsen [15] notes that the biomonitoring utilized by NASA onboard ISS is difficult to use and not user-friendly, even for trained medical professionals [15]. Given the rapid changes within the commercial healthcare industry, it can be expected that the market will outpace NASA initiatives and produce technology to meet NASA's biomonitoring need [15].

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B. Agile Architecture

To ensure the safety, comfort, and wellbeing of SFP throughout the suborbital flight regime, key biomarkers (vitals) need to be monitored for tracking the physiological and performant state of SFP. The biomarkers are selected based on their direct impact on the physiological state of SFP. Considerations are given to simplicity of adaptation, use, and comfort by SFP. Biomarkers such as blood pressure, heart rate, and oxygen level can be measured throughout the flight regime to measure and monitor changes in SFP physiological state. The flight dynamics during launch & ascent and descent & landing would impact SFP differently due to the variation and the axis of the G-forces. Considerations are given to physiological state in conjunction to the phase of flight.

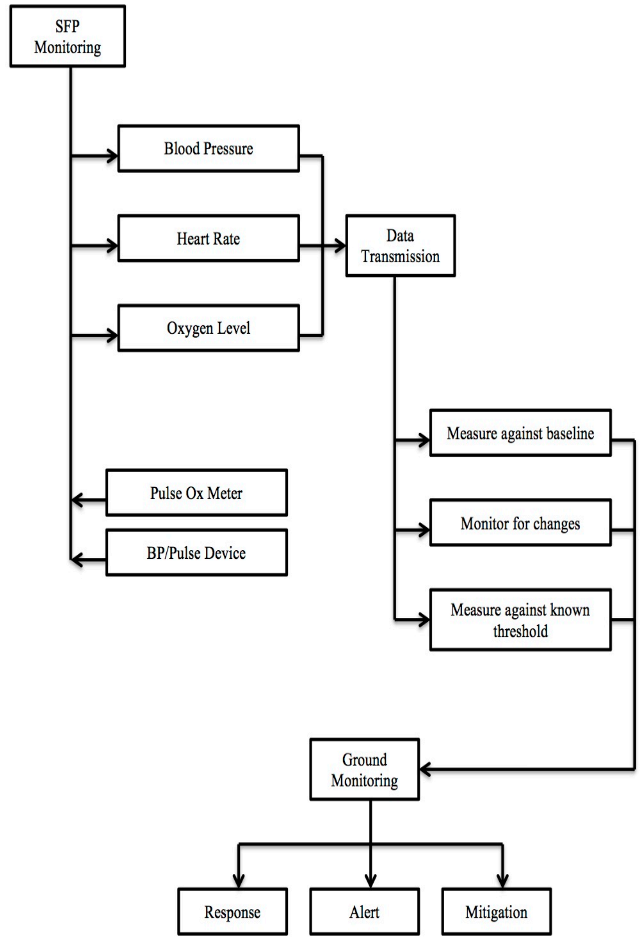

Figure 1. The Proposed agile architecture of SFP biomedical monitoring with focus on measuring, alerting, responding, and mitigation negative physiological states.

Figure 1 illustrates the proposed agile architecture of the monitoring process with emphasis on monitoring, mitigating, and responding to changes in physiological states. Keeping into consideration the variations and differences of different suborbital vehicles as well as operational procedures, an agile system that is *adaptable*, *noninvasive*, and can be *applied to multiple vehicles at minimal cost* would offer minimal barriers for adopting. The financial constraints of commercial space companies vary greatly coupled with the fact that there are no regulatory requirements for biomedical monitoring; a low-cost and low barrier would incentivize commercial space companies to adopt such a system. An agile architecture would include existing OEM devices to measure blood pressure, heart rate, and pulse ox integrated with software interface for data collection/storage, transmission, and computation.

Data being generated by SFP is transmitted to ground monitoring that would include aerospace/flight surgeon(s) and other members of an "SFP safety team". The data in (near) real-time would be consistently measured against baseline vitals measures established for each SFP prior to the flight.

C. Device and Data Collection

OEM devices with radio frequency (RF) connectivity such as the new Bluetooth 5 provide short range high-speed connectivity to transmit data from the device to a data management module. The data management module would collect, store, and transmit information to ground station for analysis and feedback. Figure 2 illustrates the data collection and transmission architecture. While the figure is

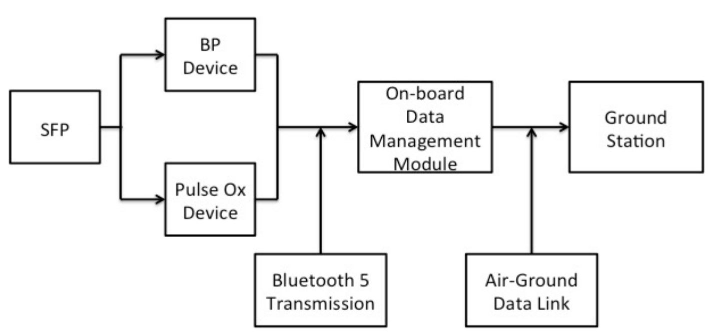

Figure 2. Biomedical medical collection and transmission

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oversimplification, the process illustrates a framework that can be adapted to numerous vehicles without significant changes to operations of the vehicles.

D. Data Processor and Software Interface

Of critical importance is a software interface to analyze, monitor, and alert based on the biomedical data transmitted for each passenger. Thresholds can be established for SFPs prior to flight to note the limits of their G-tolerances. Blood pressure, heart rate, and pulse ox measures can be correlated with acceleration for ground/operations team to monitor and observe. The correlation between G-forces and the biomarkers can provide ground team with the ability to better assess the impact of flight dynamics on SFP health. This also enables quicker response when SFP health is affected due to flight dynamics such as during high-G launches. Software algorithms designed to generate alerts, as displayed in Figure 1, when SPF vitals reach certain level or shift erratically can enable quicker response to a medical emergency or mitigate the onset of an emergency advising on specific procedures or measures to be undertaken either by the SFP or ground operator.

V. Flight and Physiologic Dynamics

Blue Origin and Virgin Galactic are most likely the only two companies in the near future to transport SFP to suborbit and back as a recurring operation using rocket propulsion [4]. Each company's respective vehicle differs drastically in terms of (a) design, (b) flight profile, and (c) seating arrangement. Taking the three aforementioned points into consideration, the physiological effects experienced by SFP *and crew* will have some degree of variance based on vehicle type.

A. Virgin Galactic

Virgin Galactic's flight vehicle, SpaceShipTwo, is designed for horizontal takeoff and horizontal landing (HTHL). The vehicle is attached to a larger plane, WhiteKnightTwo which carries SpaceShipTwo to an altitude of approximately 50,000 feet. At which point the spacecraft is released followed by ignition of its hybrid rocket engine that accelerates it to an altitude of approximately of 62 miles [17]. Figure 3 illustrates the flight profile of SpaceShipTwo and the flight loads.

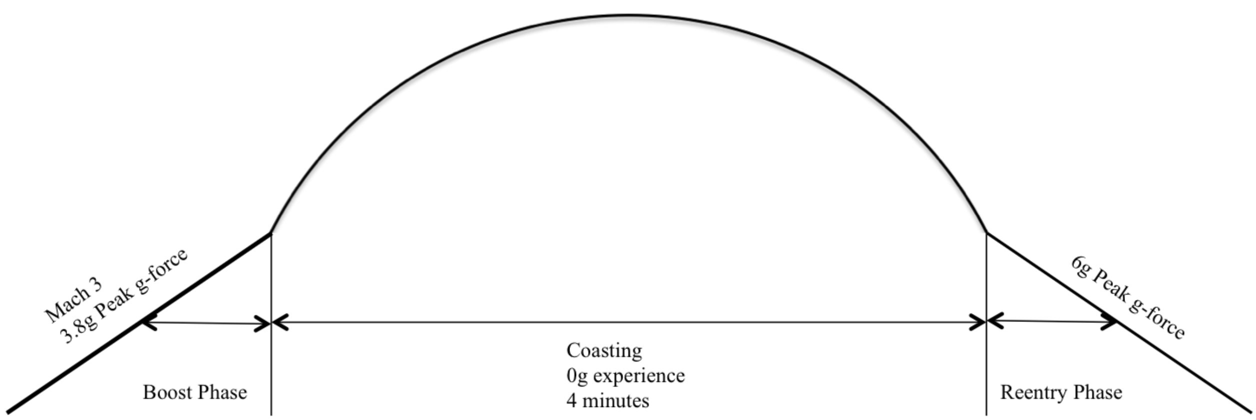

Figure 3. SpaceShipTwo flight profile.

The vehicle accelerates to Mach 3 during the boost phase reaching Mach 3 at 30 seconds after ignition and continues the boost phase for additional 40 seconds. After boost phase, the vehicle will continue to climb until it reaches peak altitude of 62 miles. As it continues to climb, the vehicle will be in coast phase during which SFP will experience 0g. After approximately 4 minutes of 0g coasting, the vehicle will begin deceleration and reentry. During this phase, the vehicle will experience 4Gz and 6Gxz – SFP will experience lesser g-forces due to reclined seats [18].

The g-forces experienced during boost and the reentry phase have the potential to substantially impact the health of the SFP as well as the crew. Whereas the crew would have adequate training to mitigate effects of high g-forces, the SFP will have little training in comparison. Special considerations for SFP monitoring must be placed during high-g regimes (Boost and Reentry) for response and recovery purposes including premature flight termination.

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B. Blue Origin

Blue Origin's New Shepard spacecraft is a rocket with a capsule on top for carrying humans to suborbital altitudes. Like conventional rockets, New Shepard is launched vertically from a launch pad to suborbital altitudes at which it releases its capsule to continue on its upwards parabolic trajectory. The rocket will fall back to earth and stabilize during the descent to land vertically. The capsule will eventually begin its descent through the parabola and eventually deploy parachutes to land back to earth. Figure 4 [19] illustrates the flight profile of New Shepard and the approximate g-forces experienced by SFP during boost and descent.

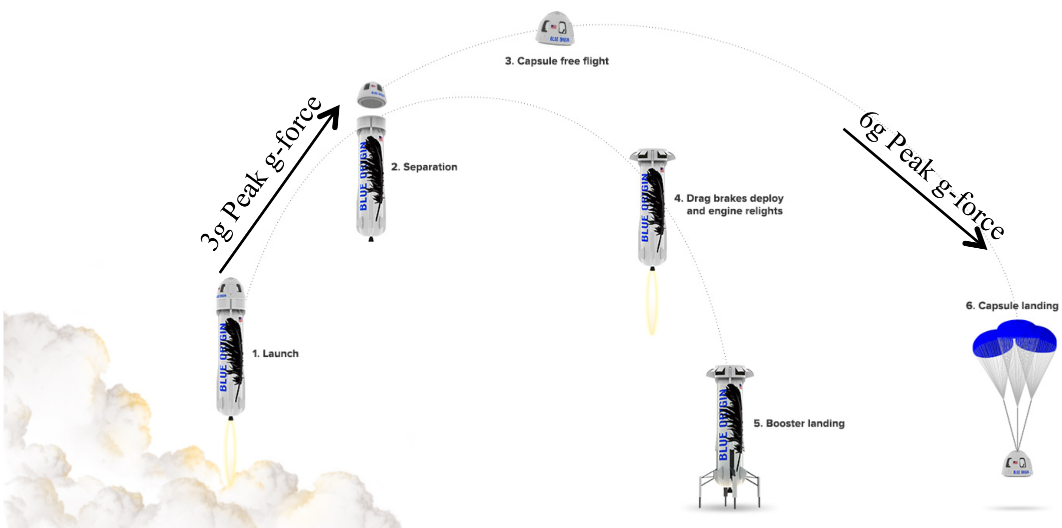

Figure 4. Blue Origin New Shepard flight profile. Source: Blue Origin.

C. Areas of Concern

As illustrated above, the boost and descent phase pose the greatest threat to SFP health – especially the descent stage due to higher g-forces experienced. G-forces during both boost and descent are limited to G+. If the g-forces are during boost are limited to 3-4g, then risk of A-LOC/grey out remains low; whereas during descent, G-LOC has greater possibility of occurrence due to peak of 5-6g. Whether the abovementioned (and similar) vehicles have variable reentry profiles to reduce the g-forces on SFP is unknown, it is also unknown if the flight can be aborted in safe manner in case of vehicle and or SFP medical emergency.

Another area of concern is the motion of SFPs in microgravity. The space motion and cardiovascular changes are a real risk that can affect strapped or free floating SFPs. There are number of risks linked to the short period of microgravity that stem from the possibility of interaction of SFPs with cabin hardware and with each other as well as missing necessary procedures in the timeline of the flight profile.

Next to number of other risks that involve use of special equipment and cabin redundancies that are vehicle and flight profile specific this paper further addresses primarily nominal environmental cabin condition. Hence known risks due to systems failure such as decompression illness due to decrease of the cabin air pressure is not discussed further. Nonetheless, the proposed biomedical monitoring system architecture may provide valuable data towards individuals' condition.

However, having greater awareness of the specific flight-related medical risks and assuring situational awareness related to SFP wellbeing can enable safer operations and quicker response.

D. Physiological Measures

Ryoo et al. [20] conducted a study to monitor the consciousness of test subjects during high +Gz using near-infrared spectroscopy (NIRS). The purpose of the study was to determine if there were physiological indicators of G-LOC that could be monitored using biomedical devices thus providing warning when an individual may experience G-LOC. Near-infrared spectroscopy was used for clinical monitoring to determine the absorption rate of oxygenated hemoglobin (HbO_2) and deoxyhemoglobin (Hb). HbO_2 and Hb are both linked to tissue oxygenation [20]. Nine test subjects were placed in the dynamic flight simulator at the Naval Air Warfare Center for multiple tests using the following scenarios:

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1) Short pulses of +6 Gz, +8 Gz, and +10Gz (From +1.25 Gz to +6 Gz, +8Gz, or +10 Gz; first set of pulses were .25 seconds and subsequent pulses were 0.5-1 second in duration)
2) Sustained plateaus of +6 Gz, +8 Gz, and +10Gz (From +1.25 Gz to +6 Gz, +8 Gz, or +10 Gz till G-LOC or 15 seconds)

Within both scenarios, a correlation was discovered between the drop in oxygen saturation (rSO_2) and G-LOC; right before the onset of G-LOC, the Hb levels rose (simultaneously HbO_2 levels dropped). Additionally, A-LOC did not necessarily occur before G-LOC. While the drop in rSO_2 was greater for short pulses, the incapacitation time (ICAP) was longer for the sustained plateaus. The authors concluded that the type of +Gz exposure (pulse or plateau) determined the duration of ICAP. For sustained plateaus, the ICAP was longer but the rSO_2 drop was not as significant as that during the +Gz pulses. One reason may have been due to the fact that the tissue compensated for sustained plateau thereby adjusting the rSO_2 levels. However, once the rSO_2 dropped to certain level, the test subjects lost consciousness and remained unconscious for 16 seconds or more.

Both short duration pulses and sustained plateaus pose unique problems; having demonstrated correlation between A-LOC/G-LOC and rSO_2 levels, the author's findings provide an opportunity for prototyping and implementation within operational environment for validation purposes. The flight profiles of the two suborbital vehicles discussed in this paper provide an overview of the dynamic g-forces environment encountered by the occupants of the vehicles. Both launch & ascent and reentry & descent would entail a combination of +Gx and +Gz on the human body.

As such, maintaining rSO_2 and SpO_2 reading of SFP throughout the flight regime can greatly improve safety and situational awareness and alert ground team of a potential A-LOC/G-LOC.

In 2012, Astronauts4Hire, a not-for-profit private astronaut training company, partnered with a digital health company and a medical device provider to develop a commercially viable solution for monitoring individuals within dynamic gravity environment [21]. However, the project has not seemed to progress after initial development.

E. Radiological Considerations

Copeland [22] indicated that the FAA accepts recommendations made by the American Conference of Government Industrial Hygienists limiting crewmembers to a 5-year average effective dose of 20 millisieverts per year with maximum of 50 millisieverts within a single year [22]. The risk involved is equivalent to four fatal cancer cases per 100,000 people exposed to 1 millisieverts. However, due to the expected short duration of suborbital flights, the effective dose for occupants is expected to be low. The dose experienced by Alan Shepard during the Mercury 3 flight was 0.00031 millisievert [22].

Additionally, research by Turner [23] indicated that expected radiation exposure by occupants onboard suborbital vehicles range between 0.34 to 2.64 microSv whereas exposure during a regular commercial cross country flight would be 25 microSv. Exposure will vary based on the altitude and more importantly latitude [23]. However, Turner's [23] findings indicated that fatalities would be at fewer than one excess cancer related fatality per million flights [23]. Nontheless, radiation environment of suborbital and orbital flight remains of a high risk for potential pilots who would repeatedly pilot the commercial space vehicle.

VI. Proposed Solution

A. Architecture

The proposed biomedical monitoring system architecture is based on 'agile' concept. Within the context of this paper, 'agile' and 'agile architecture' refer to a system that is (a) *adaptable*, (b) *easily deployable*, and (c) *lightweight*. These three factors can impact the cost, implementation, and management of a biomonitoring system. Given the rapid advancements in mHealth (mobile health) technologies, smartphone applications for monitoring health and safety of patients, the transference and application of mHealth platforms (the earth to space spinoffs) for biomonitoring offers certain advantages over building systems ground up:

1) Cost savings by adapting existing solutions for aerospace needs
2) Reduced complexity for integration with enterprise IT infrastructure
3) Implementation flexibility by utilizing 'plug and play' concept to meet organizational needs without burden of excessive development
4) Reduce the burden of in-house systems maintenance and management
5) Harmonize standardizations based on existing industry platforms

Current mHealth platforms utilized for remotely monitoring patients can record and track patient vitals from Bluetooth medical devices as well as alert clinicians to fluctuations in patient health. Similarly, the implementation

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of a mHealth platform within commercial suborbital flight domain can enable the monitoring of SFP and determine onset of A-LOC/G-LOC or other adverse physiological states. Consequently, the adaptation of mHealth platforms to aerospace must address inflight-to-ground system data transmission within the parameters of existing and emerging avionics bus. Considering that A-LOC and G-LOC events have correlation to tissue oxygenation levels [20] and are indicative of onset of these events, maintaining consistent readings of tissue oxygen level is relevant, a simple pulse oximeter device might provide valuable insights in the state of the oxygen-levels present within SFP. Additionally, if the readings are correlated with the existing g-load of the vehicle in real-time, that can provide a robust situational awareness. Furthermore, blood pressure and heart rate readings provide secondary insights into the physiologic state of SFP. Even in the absence of A-LOC/G-LOC, SFP may experience cardiovascular strain that could induce other physiological problems. Since g-forces and accelerations have direct impact on tissue oxygen and cardiovascular functions, it is imperative to monitor both functions within SFP.

B. Components

The proposed system architecture is comprised of two separate sub-architectures – ground-based monitoring and inflight system as displayed in figures 6 and 7 respectively. The ground-based system is comprised of a server where a mHealth system is housed and computer terminals for members of ground team to access and monitor SFP health. The platform displays (near) real-time vitals information on patient tissue oxygen levels, blood pressure, and heart rate. Alerts can be preconfigured within the platform to trigger warnings when vitals reach beyond a certain threshold. Additionally, video monitoring can be included as part of the system to ensure there is visual monitoring and verification of SFP. Tissue oxygenation, blood pressure, and heart rate measurements above pre-established baseline levels would trigger automated alerts within the software dashboard for ground monitoring team to respond to. Additionally, the inclusion of cabin-based video camera(s) would provide greater situational awareness, redundancy, and visual reference for validation.

The inflight system is comprised of wearable medical devices (Pulse Ox, BP & Heart rate) connected via Bluetooth to an onboard front-end application which in turn can utilize a vehicle bus (ARNIC 629 or emerging bus) to transmit data to ground system. Within the ground system, data would be measured against pre-existing vitals threshold established for each SFB prior to flight during medical screening. Within figure 7, the section marked with blue dotted line indicates an onboard system that replicates the same function as the ground-based monitoring system for the purpose of providing redundancy as well as rapid alerts to occupants. Of course that particular segment of the system may be excluded from the overall architecture as well.

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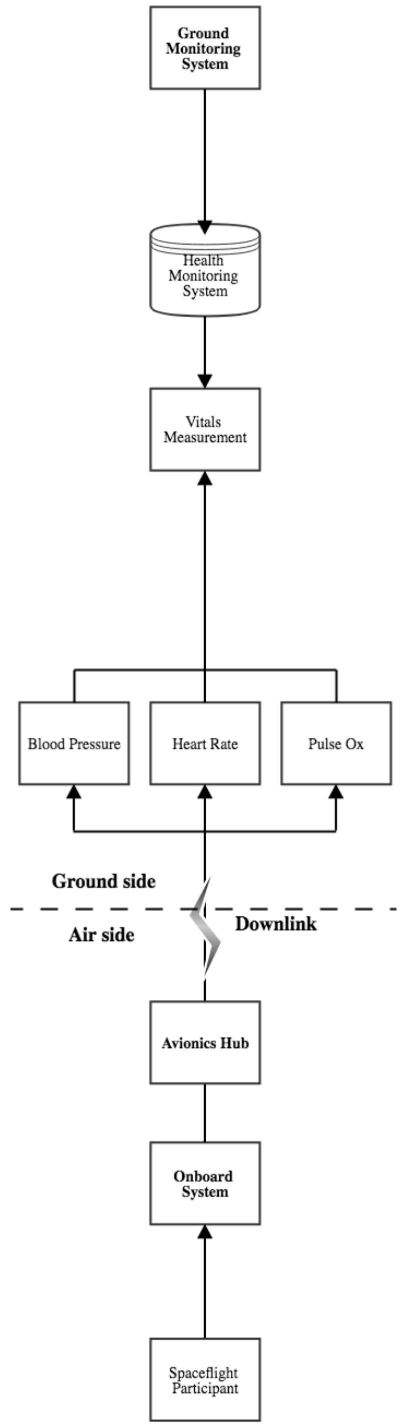

Figure 5. System architecture for biomedical monitoring system

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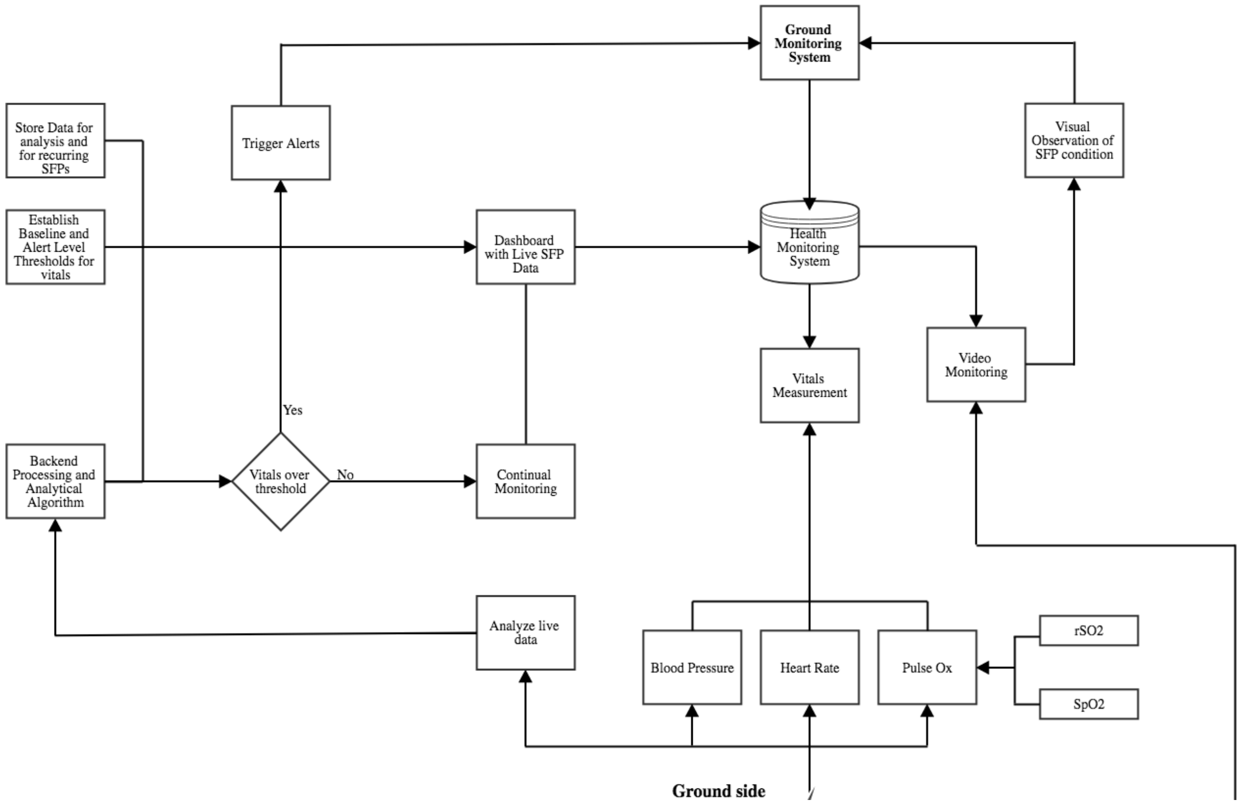

Figure 6. Ground-side bio-monitoring system architecture.

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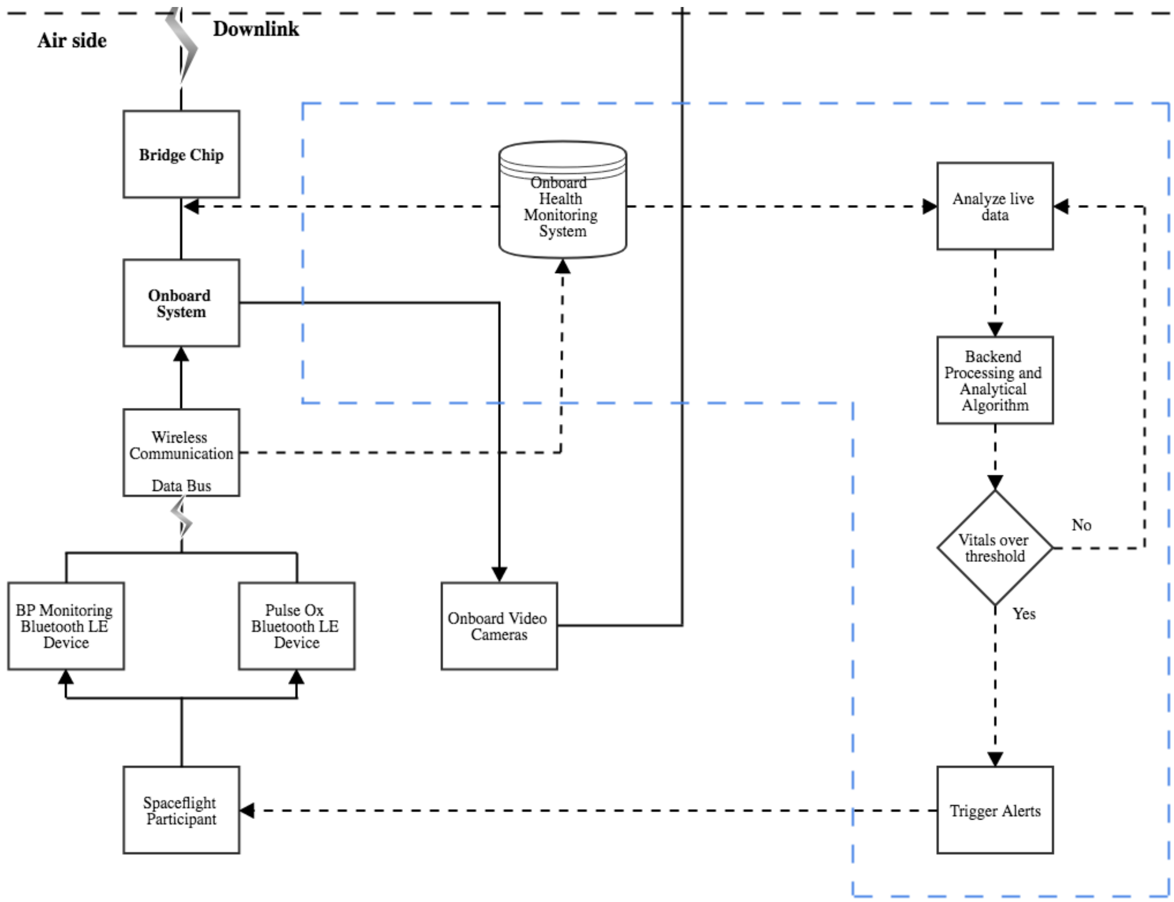

Figure 7. Onboard bio-monitoring system architecture.

VII. Commercial Human Spaceflight and Health Care

As the commercial human spaceflight progresses, more passengers would be flown to space on regular bases. HSF though is subject to extreme environments that may limit the experience of space to certain people due to their health condition. The HSF provider will most probably require a health waiver from a doctor as well as an FAA required life waver.

Current US health care system does not allow collecting private information but the e-health evolution may assure significant changes and spaceflight providers to be required to establish relation with the e-health providers or the DB providers. E-health platforms could support necessary pre-screening portals for future SFPs. The content of the data accessed would be subject to relevance to HSF. Additionally, as noted by Antonsen [15], the rapid progress of commercial development within the e-health domain will outpace the progress within NASA and related research funded by NASA. As such, it is critical to look to emerging solutions within the market for discovering the suitability of transplanting e-health solutions into the aerospace domain. Some advanced emerging solutions within e-health domain that are worthy for study for suitability include DocToDoor, HealthLoop, and Cloud Well Labs amongst many others. In fact, these sorts of solutions can offer multiple benefits:

1) Enable effective pre-flight medical screening assessment and medical data storage
2) Collect and analyze patient-generated data in (near) real-time environment during pre-flight, inflight, and post-flight
3) Enable potential deployment of single system for pre-flight screening, inflight monitoring, and post-flight readings
4) Help establish dynamic database of SFP health for further assessment in the future

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While the space industry has led to many innovations that have affected other industries. The growth within the e-health industry can benefit both commercial and government space travel enabling the expertise of both industry domains to come together. As mentioned earlier in the paper, the ability of commercial space enterprise to leverage existing and emerging capabilities within the e-health domain not only provide an effective biomonitoring system but also reduce cost associated with building and managing an in-house system.

In the current state of affairs, it is imperative to first establish a joint (commercial spaceflight) industry standard for a biomonitoring system that provides certain baseline requirements for such systems. Development of such standards should ideally be done with the inclusion of e-health industry, research institutions, universities and the FAA/AST. Establishing industry working group with a road map to prototype e-health solutions within the coming few years can help test and validate potential solutions and help develop future guidelines, especially for the next decade when proliferation of commercial spaceflight would impact more and more individuals.

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