BEFORE THE

Federal Communications Commission

WASHINGTON, DC 20554

In the Matter of	)	
	)	
Amendment of Part 2 of the Commission's Rules for Federal Earth Stations Communicating with Non-Federal Fixed Satellite Service Space Stations;	)	ET Docket No. 13-115
	)	RM-11341
	)	
Federal Space Station Use of the 399.9-400.05 MHz Band; and	)	
	)	
Allocation of Spectrum for Non-Federal Space Launch Operations	)	

To: The Commission

COMMENTS OF BIGELOW AEROSPACE, LLC

Bigelow Aerospace, LLC ("Bigelow Aerospace"), by its attorneys and pursuant to Sections 1.415 and 1.419 of the Commission's Rules (47 C.F.R. §§ 1.415 & 1.419), hereby comments on the above-captioned Notice of Proposed Rulemaking and Notice of Inquiry ("*NPRM & NOI*").[1] In the *NPRM* portion of the document, the Commission makes several spectrum allocation proposals relating both to Federal earth stations that communicate with non-Federal space stations and to commercial space launches. The Commission also seeks comment in the *NOI* portion on future spectrum needs to meet the communications requirements of emerging space-based technologies, including commercial space stations. Bigelow Aerospace limits its comments to the *NOI*, addressing in particular the future bandwidth needs of various

[1] *See Amendment of Part 2 of the Commission's Rules for Federal Earth Stations Communicating with Non-Federal Fixed-Satellite Service Space Stations et al.*, FCC 13-65, Notice of Proposed Rulemaking and Notice of Inquiry, ET Dkt. No. 13-115, *slip op.* (released May 9, 2013).

crewed space stations and spacecraft for telemetry, tracking, control, communications, and safety-of-life applications.

I. Background: Bigelow Aerospace's Development of Expandable Habitats for Human Spaceflight

Bigelow Aerospace was founded in 1999 with the purpose of revolutionizing space commerce and exploration via the development of next-generation expandable space habitats, a concept originally promoted by NASA in the 1990's. Despite the promising nature of the technology,[2] NASA ended its program over a decade ago due to budget and political constraints.[3] Bigelow Aerospace subsequently licensed the technology from NASA in 2003, obtaining exclusive commercial rights to bring the concept of expandable habitats to fruition.

Beginning with the launch of Genesis I in 2006, Bigelow Aerospace has successfully deployed two prototype spacecraft that are sub-scale versions of future crewed systems that are already under development.[4] The Genesis spacecraft have provided invaluable data to Bigelow Aerospace regarding the performance of expandable habitats in an actual on-orbit environment. All of this work had been paid for exclusively by company founder and President Robert T. Bigelow. No government funds or external financing of any kind have been accepted by Bigelow Aerospace for its primary habitat development program.

By 2009, NASA became interested in leveraging Bigelow Aerospace's unprecedented investment and progress, and initiated discussions to attach an expandable module to the

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[2] Among other advantages, expandable habitats offer substantially more volume than traditional metallic structures while also providing enhanced protection against radiation and physical debris.

[3] *See* Public Law No. 106-391, "National Aeronautics and Space Administration Authorization Act of 2000" (denying NASA budgetary authority to pursue additional research on expandable space habitats).

[4] Genesis I, essentially cylindrical in shape, is 14.5 feet long and has a deployed diameter of roughly 8 feet, with a weight of approximately 2,600 lbs. Genesis II, weighing approximately 2,800 lbs., is the same length as Genesis I although its fully deployed diameter is about 10 feet.

International Space Station ("ISS"). In December of 2012, Bigelow Aerospace and NASA executed an agreement for the Bigelow Expandable Activity Module ("BEAM") which is currently under development at Bigelow Aerospace's North Las Vegas facility and is expected to be launched and berthed to the ISS in June of 2015.[5]

In addition to the BEAM, Bigelow Aerospace is also actively developing the BA 330. The BA 330 will provide roughly 330 cubic meters of internal volume and an individual BA 330 habitat can support a crew of up to six (equal to that of the current crew compliment of the entire ISS). Each BA 330 can operate as an independent space station or can be interconnected with other BA 330s to provide for additional volume and capacity. Initially, Bigelow Aerospace's plan is to deploy an 'Alpha Station' comprised of two BA 330s.

The business plan for the Alpha Station is to service a variety of public and private clients. Currently, Bigelow Aerospace is actively reaching out to sovereign nations that (1) already have human spaceflight programs but would like to lower their costs while increasing the size and capabilities of their astronaut corps, and (2) nations that would like to take their first steps into the world of astronautics in an affordable fashion. The company is also targeting major corporations with an interest in microgravity research and development, particularly those in the pharmaceutical and biotech sectors. Additionally, space tourism, which has already been taking place aboard the ISS, may also be a part of Bigelow Aerospace's activities since the company will be able to offer an unparalleled experience at a price far below historic costs. Finally, Bigelow Aerospace has plans to move beyond low-Earth orbit, and is already working

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[5] *See, e.g.,* Kenneth Chang, "For Space Station, a Pod That Folds Like a Shirt and Inflates Like a Balloon," *New York Times,* at A15 (January 17, 2013).

with NASA to explore leveraging its systems and spacecraft to pursue missions to Lagrange points, lunar orbit, or the surface of the Moon.[6]

II. Bigelow Aerospace's Existing Use of Spectrum under Agreements with NASA and FCC-Issued Experimental Licenses

None of Bigelow Aerospace's current or future operations would be possible without access to bandwidth enabling it to track and control its space stations and spacecraft, upload and download data from onboard computers, and communicate on a real-time basis with crew and clients. To date, Bigelow Aerospace has gained access to the requisite spectrum both through its relationship with NASA, and by obtaining experimental licenses from the FCC.

The company executed a Space Act Agreement with NASA in May 2006 that allowed the Genesis missions to use S-Band frequencies in the ranges 2025-2110 MHz and 2200-2290 MHz for both uplink and downlink transmissions. The Genesis expandable modules were also constructed to utilize VHF and UHF frequencies at 145-146 MHz, 401-401.7, and 402.4-403 MHz to which Bigelow Aerospace has been granted access under a series of FCC experimental licenses dating back to 2005.[7] The Genesis spacecraft primarily use the S-Band frequencies for data download and VHF/UHF for command and control requirements.[8]

At the time of the launch of Genesis I, Bigelow Aerospace maintained a single ground station at its North Las Vegas, Nevada facility. When Genesis II launched in 2007, the company had added two more ground stations, one in Fairbanks, Alaska and another in Naalehu, Hawaii.

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[6] A more detailed description of Bigelow Aerospace's past accomplishments, as well as present and future plans, is attached hereto as Attachment A.

[7] *See* FCC Experimental Call Signs WD2XWW and WD2XND.

[8] In June of 2007, Bigelow Aerospace was also granted an experimental license to explore the use of X-Band spectrum at 8482-8492 MHz on its space stations. *See* FCC Experimental Call Sign WE2XFH. Bigelow Aerospace also maintains an experimental license for a GPS re-radiator, which supports its work at its North Las Vegas facility. *See* FCC Experimental Call Sign WE2XMU.

Since that time Bigelow Aerospace has constructed one additional ground station, which is located at Loring Air Force Base in Aroostook, Maine.

III. Bigelow Aerospace's Spectrum Requirements for Future Space Stations/Spacecraft Communications Needs

In order for Bigelow Aerospace to successfully implement its long-term plans, reliability and sustainability of the communications architecture will be a necessity. As noted above, the initial Genesis test modules have relied solely upon Space Act Agreements with NASA and experimental licenses from the FCC to meet the short-term goals of the program. However, as Bigelow Aerospace moves to full-scale production and marketing of human-rated space stations and other spacecraft, it will require assurance that spectrum access obtained from the FCC will be viable for the extended service lifespans of Bigelow Aerospace systems.

Bigelow Aerospace spacecraft will be used to support a variety of different mission scenarios. The complexity of basic station/spacecraft operations plus the needs of customer communications must be accounted for in a holistic communications plan. In order to support just its initial 'Alpha Station,' Bigelow Aerospace anticipates spectrum needs in the following bands for the following uses, as detailed more fully in the following section:

Bigelow Bandwidth Requirements for the Alpha Station (comprised of two BA 330s)			
VHF	Uplink	GMSK	20 kHz
UHF	Downlink	GMSK	20 kHz
S-Band	Downlink	SOQPSK	2 MHz
S-Band	Uplink	SOQPSK	2 MHz
X-Band	Downlink	SOQPSK	10 MHz

The total number of licenses required by Bigelow Aerospace will ultimately depend on the number of independent stations and other spacecraft to be operated, as well as their orbital geometry. Stations/spacecraft at significantly different inclinations will be capable of using the same channels without risk of interference. As more Bigelow stations and spacecraft are deployed and/or other entities launch their own commercial space systems, additional channels will be needed to accommodate growing bandwidth use.[9]

1. Communication Criticality and Allocation Considerations

Bigelow Aerospace stations and spacecraft will require communications links supporting a range of services, from intermittent data transmission to critical telemetry and control operations to emergency safety-of-life communications. Accordingly, there are significant variations in the criticality of the communications links.

Telemetry and command and control services must be within frequency bands that have little degradation from rain or atmospheric effects. The band must allow for non-interference from other users. There must be sufficient bandwidth allocated to allow multiple space stations/spacecraft to communicate simultaneously to co-located ground stations to support events such as module or spacecraft dockings in orbits that result in conjunctions or overlapping communications footprints. Typically, frequencies in the S-band are appropriate for these functions.

The emergency audio/data backup services must be within a band that can allow for very high reliability and non-interference from other users, but only need a limited amount of bandwidth. Typically, lower VHF/UHF frequencies are appropriate for these functions.

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[9] A Technical Annex providing additional detail concerning Bigelow Aerospace's anticipated spectrum requirements is attached hereto as Attachment B.

Higher data rate functions such as video or customer data links are not as mission or real-time critical such that brief outages due to local weather events or other momentary interruptions can be tolerated. Higher frequencies in the X-band range are preferred for these functions.

Space-to-Space communications functions will mostly be employed during docking maneuvers and occur over relatively short-range. Because these communications will be taking place on-orbit, there are no real atmospheric concerns and very little expected interference from other users. Bigelow Aerospace believes the existing frequency bands already allocated for short-range, fixed, line-of-sight services will be sufficient to meet these needs.

2. Specific Frequency and Bandwidth Allocation Requirements

a. Emergency Audio/Data Backup Links

Emergency audio/data and backup communications links require relatively limited bandwidth allocations. Due to the criticality of these communications, however, these links need to be highly reliable and protected from interference. A minimum bandwidth of 150 kHz should be allocated for both the Earth-to-space and space-to-Earth links. This will allow multiple channels to be available to support simultaneous operations. The 399.9-400.05 MHz frequency band, the 400.15-401 MHz frequency band, or the 401-402 MHz frequency band allocation should be modified to allow for both Federal and non-Federal use on a co-primary basis. Alternatively, a portion of the 420-430 MHz band could be carved out for these links. Additionally, an allocation should be made within the 148-149.9 MHz frequency band or the 149.9-150.05 MHz frequency band to allow for both Federal and non-Federal use on a co-primary basis.

b. Space Station/Spacecraft Operations Downlink

Space station/spacecraft telemetry downlinks require a larger bandwidth to support the various activities of nominal operations. These activities encompass the telemetry communications needed to monitor equipment, nominal audio/video communications between an orbital crew and ground support, and picture/video (low definition) downloads. These are core activities needed to maintain operations and ensure the safety of the crew. A minimum of 25 MHz should be made available to support multiple channels of 5 MHz bandwidth. The 2200-2290 MHz frequency band allocation should be modified to add support for both Federal and non-Federal use on a co-primary basis.[10] Division of the band into multiple sub-channels of 2207-2219 MHz, 2270.5-2274.5 MHz, and 2285-2290 MHz would be acceptable. Alternatively, the Commission could modify the allocation in the 2360-2395 MHz frequency band to add support for non-Federal use on a co-primary basis.

c. Space Station/Spacecraft Operations Uplink

Space Station command uplinks support the complimentary activities of the telemetry downlinks. These activities encompass the commands needed to control equipment, nominal audio/video communications between ground support and astronauts, and picture/video (low definition) uploads. These are core activities needed to maintain operations and ensure the safety of the onboard crew. A minimum of 25 MHz should be allocated to support multiple channels of 5 MHz bandwidth. The 2025-2110 MHz frequency band should be modified to add support for both Federal and non-Federal use on a co-primary basis. Alternatively, the 1626.5-1660 MHz frequency band could be modified to add support for commercial use on a co-primary basis.

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[10] No restrictions should be placed on the locations for transmit/receive stations used for space station/spacecraft operations uplinks or downlinks, as described here in subsections b and c.

d. Customer Support Links

Beyond the normal operations of supporting a human-rated space vehicle, frequency allocations are needed for the support of customer payloads and customer audio/video communications. While these services are not critical to the safety and welfare of the onboard crew or clients, they do require a relatively large bandwidth allocation to support the expected data transfers from experiments and customer bi-directional communications. The 8450-8500 MHz band allocation should be modified to add support for both Federal and non-Federal use on a co-primary basis. This would support five channels of 10 MHz bandwidth each.

In order to support customer uplink communications, there should be a corresponding allocation made for a minimum of five channels of 5 MHz bandwidth each. The 7145-7190 MHz band or 7190-7235 MHz band could be modified to add support for both Federal and non-Federal use on a co-primary basis.

IV. Bigelow Aerospace Proposes a New Service Designation to Cover Human Space Operations

Historically, there has been little need to distinguish bands allocated for non-Federal Government use between regular satellite/space launch communications and human spaceflight communications. There was sufficient bandwidth allocated under the designation of "SPACE OPERATIONS" and the control of all human spaceflight operations by the Federal Government assured that there was little risk of interference. Any harmful interference issues could be resolved through coordination via the Federal Government interagency process. However, as the international use of space has increased, the frequencies designated for "SPACE OPERATIONS" and other space-related services are now being sought for utilization by both Federal and non-Federal users for activities that have varying levels of criticality.

Communications services that have a direct impact upon the health and safety of crewed space vehicles and stations should take precedence over typical space-related communications.

With the increasing number of human spaceflight activities being planned to support both private and public programs, and the planned introduction of commercial services not directly administered by the Federal Government, a new service designation should be added that better describes the nature of the spectrum use. Bigelow Aerospace proposes the adoption of a new service designation specifically for "HUMAN SPACE OPERATIONS," which would differentiate the allocation from the current satellite and space operations services (*e.g.*, SPACE OPERATIONS, SPACE RESEARCH, etc.). The new designation would be applied to applications where the communications directly affect the health and welfare of a crewed space vehicle/station, *i.e.*, all those links described in the foregoing section except those designated for customer support (video and data uploads and downloads). Bigelow Aerospace believes a better description of the use of the frequency band allocation will help in the resolution between or among primary users within the protected band of interference issues.

V. Conclusion

The foregoing proposals reflect the anticipated frequency allocations needed to support Bigelow Aerospace orbital stations and spacecraft (additional spectrum will need to be allocated to support transport vehicles carrying crew and cargo to such stations/spacecraft). The proposed allocations should be sufficient for Bigelow Aerospace's needs for the initial decade of currently anticipated operations. Because the launch of its ISS module (the BEAM) will occur in less than two years, and the company plans to deploy its Alpha Station only a year or two after that, Bigelow Aerospace urges the Commission to move on an expedited basis to advance a rulemaking proposal based on the public input received in response to its *NOI*.

Respectfully submitted,

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ATTACHMENT A

Bigelow Aerospace: Past, Present, and Future Activities

Founded in the spring of 1999 and located in North Las Vegas, Nevada, the exclusive mission of Bigelow Aerospace, LLC ("Bigelow Aerospace" or "BA") is to revolutionize space commerce and exploration via the development and utilization of next-generation expandable space habitats.

The concept of expandable space habitats was originally developed by NASA in the 1990's, first as a means of safely transporting astronauts to and from Mars and later as a crew habitat for the International Space Station ("ISS"). Expandable habitats offer substantially more volume than traditional metallic structures while also providing enhanced protection against radiation and physical debris. Additionally, expandables take up less rocket fairing space, are lighter, and, perhaps most important of all in these fiscally constrained times, Bigelow Aerospace can produce these habitats at dramatically lower prices than the conventional rigidized structures used on the ISS today.

Despite the promising nature of expandable habitat technology, due to financial and political concerns, NASA's work on expandable habitats was terminated. However, in 2003, Bigelow Aerospace, which had already begun developing such systems, executed a series of licensing agreements with NASA granting BA exclusive commercial rights to bring the concept of expandable habitats to fruition. While Bigelow Aerospace received legal authority to NASA's intellectual property under these licensing agreements, very little actual engineering work had been done by the Agency, and BA was left to take this technology from idea to reality. No prototype expandable habitats had ever been built much less launched into space. Therefore, Bigelow Aerospace initiated the Genesis program, with the goal of designing, constructing, and launching sub-scale pathfinder spacecraft that would validate the potential and promise of expandable habitats in an actual, orbital environment. Although these prototype spacecraft are sub-scale versions of future Bigelow systems they are still quite substantial. For example, Genesis I, which is essentially cylindrical in shape, is roughly14.5 feet long and has a deployed diameter of 8.3 feet, with a weight of approximately 2,800 lbs.

To deploy Genesis I, Bigelow Aerospace hired ISC Kosmotras, a joint Russian-Ukrainian company that takes decommissioned SS-18 'Satan' missiles (Soviet era ICBMs), replaces the rockets' warheads with fairings and avionics produced by Yuzhnoye, and thereby provides low-cost commercial space launches via an extremely accurate and well proven system. On July 12, 2006, Genesis I was launched from Yasny, an active Russian Strategic Rocket Forces nuclear missile base that also hosts Kosmotras's private sector facilities and operations. The launch of Genesis I was extremely successful, with the Dnepr (the name of the SS-18 in its commercial configuration) placing the spacecraft within 400 meters of Bigelow Aerospace's desired orbital injection point.

Images taken of and by Genesis I in orbit

The purpose of the Genesis I mission was primarily to test and validate the envelope of the spacecraft and to demonstrate the technology's general viability and potential (some industry skeptics didn't even believe that expandables could survive the launch environment). Genesis I exceeded Bigelow Aerospace's most optimistic expectations. The mission involved not just trailblazing technology, but numerous historic firsts. For example, Genesis I represented the first time that an expandable habitat prototype had ever been constructed, much less launched into space. It was also the first spacecraft ever produced by Bigelow Aerospace, the first time that the Dnepr had carried a single large integrated payload (previous Dnepr launches had always carried several smallsats), and it was the first time that any commercial launch activity had ever taken place from Yasny, an active Russian nuclear missile base. Despite long odds, Bigelow Aerospace's terrestrial testing and manufacturing prowess paid off, and Genesis I proved that expandable habitat technology could deliver on its promise of greater capabilities at lower costs. Throughout its operational lifetime, the internal atmospheric leak rate of Genesis I remained undetectable, validating the BA team's highest hopes for envelope integrity.

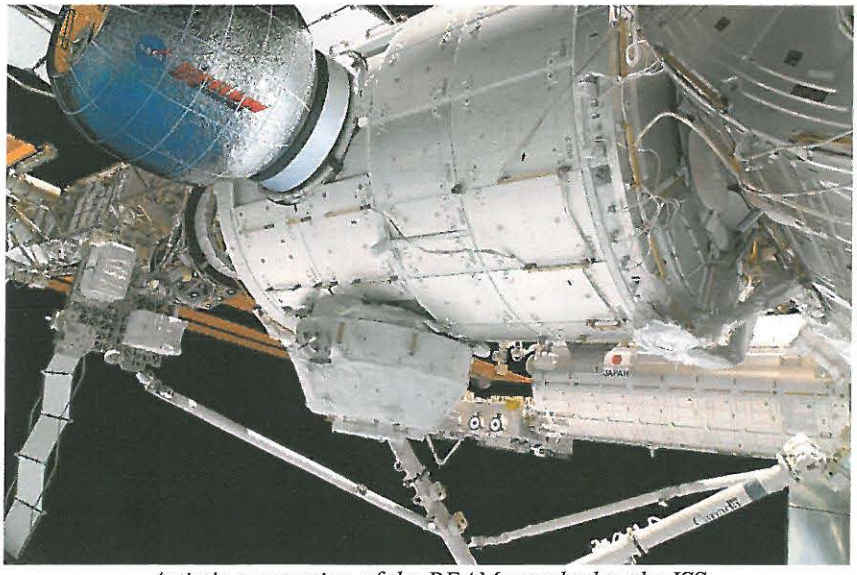
Due to the success of Genesis I, Bigelow Aerospace was able to do much more with Genesis II. Genesis II carried roughly triple the amount of sensors and cameras than its predecessor, and since the basic structure and envelope had already been proven, the spacecraft also included new subsystems such as a reaction wheel. Because of all of this, Genesis II, while essentially retaining Genesis I's dimensions, was heavier, weighing approximately 2,900 lbs.

Since Kosmotras had provided a flawless launch for Genesis I, Bigelow Aerospace exercised a contractual option for the company to deploy Genesis II on a Dnepr from Yasny. On June 28th, 2007, less than a year after the launch of Genesis I, Genesis II successfully achieved orbit. Kosmotras did another excellent job, placing Genesis II within 100 meters of BA's desired orbital injection point.

The Genesis spacecraft provided invaluable data to Bigelow Aerospace regarding the performance of expandable habitats in an actual on-orbit environment. The Genesis program raised the Technology Readiness Level of this innovative system from 2 or 3 to a robust 6 or 7. In addition to validating the potential and promise of expandables, the Genesis missions bolstered Bigelow Aerospace's visibility and the credibility of 'commercial' space in general. All of this work had been paid for exclusively by company founder and President Robert T.

Bigelow. No government funds or external financing of any kind have been accepted by Bigelow Aerospace for its primary expandable habitat development program. By 2009, NASA became interested in leveraging Mr. Bigelow's unprecedented investment and progress, and initiated discussions to place a Bigelow module onto the Agency's crown jewel of human spaceflight, the ISS.

After three years of analysis, testing, and even fabrication of test hardware by Bigelow Aerospace (again, without receiving any government funds), in December of 2012, BA and NASA executed an agreement for the Bigelow Expandable Activity Module ("BEAM"). Currently under development at Bigelow Aerospace's North Las Vegas facility, the BEAM, when fully deployed, will be approximately 13 feet long with a 10.5 foot diameter, and will weigh roughly 3,000 lbs. The BEAM will be launched to the ISS on a Dragon capsule during SpaceX's Cargo Resupply Services Mission 8, nominally scheduled for June of 2015. The BEAM will travel inside the 'trunk' of the Dragon. After the Dragon berths with the ISS, the Station's arm will remove the BEAM and connect it to the aft port of Node 3. Subsequent to the successful completion of this process, the BEAM pressurization sequence will be activated by astronauts aboard the ISS. Once the BEAM is fully pressurized and signals that deployment is complete, an ISS astronaut will become the first person to ever step inside and utilize an expandable habitat.

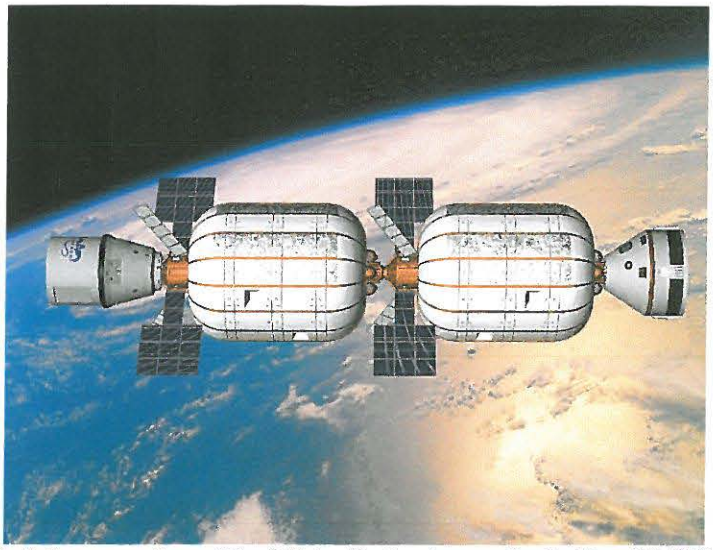


Artist's conception of the BEAM attached to the ISS

The BEAM will remain attached to the ISS for a nominal period of two years. At the end of this period NASA will either decide to keep the BEAM attached to the ISS for an additional amount of time or the BEAM will be ejected, move away from the Station, and safely burn up upon reentry.

In addition to the BEAM, Bigelow Aerospace is also actively developing the BA 330. As the name indicates, the BA 330 will provide roughly 330 cubic meters of internal volume and an individual BA 330 habitat can support a crew of up to six. Each BA 330 can operate as an independent space station or can be interconnected with other BA 330s to provide for additional

volume and capacity. Initially, Bigelow Aerospace's plan is to deploy an 'Alpha Station' comprised of two BA 330s. These BA 330s will be launched into low Earth orbit ("LEO") by Falcon Heavies, Atlas V-552s, or equivalent rockets.



Artist's conception of the 'Alpha Station' comprised of two BA 330s

The business plan for the Alpha Station is to service a variety of public and private clients. BA's initial focus has been on foreign space agencies. Currently, the ISS can support six astronauts, usually three Russians, two Americans, and one from another partner nation. Bigelow Aerospace believes that global demand for astronautics cannot be satisfied by a single rotating seat aboard the ISS for every country other than the U.S. and Russia. For example, even ISS partner nations such as Japan or Canada would like to launch more astronauts, particularly if the cost of doing so is substantially less than what they pay to send astronauts to the ISS. Additionally, countries that haven't flown astronauts before, such as the United Arab Emirates or Singapore, might wish to initiate their own human spaceflight programs, particularly if this could be done in an affordable fashion. Moreover, it's worth noting that astronauts aboard the ISS must devote the lion's share of their time to station maintenance and operations, whereas astronauts aboard the BA Alpha Station will be able to devote their time exclusively to their own activities because the Bigelow crew will be responsible for both running and repairing the station. This is a significant benefit that will substantially enhance the value of a nation's human spaceflight program.

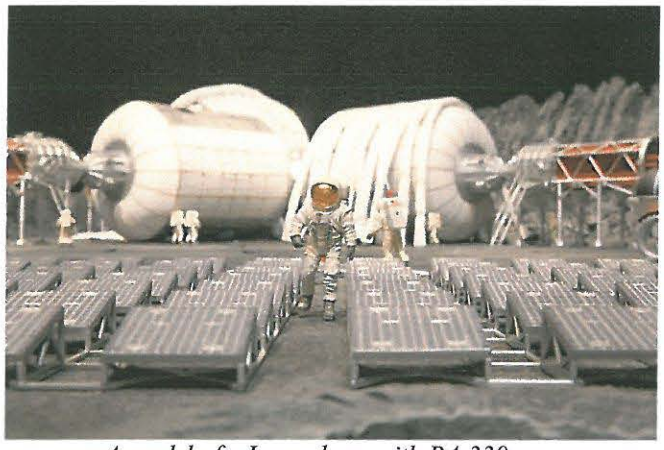
Beyond the sovereign client market, Bigelow Aerospace is also targeting corporations with an interest in microgravity research and development. Microgravity represents an entire new arena for a wide variety of commercial and scientific endeavors. Work on the ISS is already generating promising results and near-term potential exists for important and lucrative breakthroughs in the pharmaceutical and biotech sectors. Bigelow Aerospace expects that its sovereign client astronauts will focus a great deal of their efforts on microgravity R&D, particularly on work impacting the biotech / next-generation drug development field, and that corporations will quickly develop an interest in space-based manufacturing activities and utilizing astronauts of their own.

Potential also exists for a wide variety of media opportunities from television shows and movies to advertising. Commercial space operations have already captured the public's imagination across the globe and numerous companies will want to leverage the world-wide media coverage that Bigelow Aerospace's operations will garner.

Finally, tourism has already been a part of the ISS program and this will likely continue to be true for Bigelow Aerospace, which will be able to provide visitors with an affordable and unparalleled experience.

Although the Alpha Station will be Bigelow Aerospace's first platform in LEO it won't be alone for long. Bigelow Aerospace plans to launch additional stations each tailored to meet the specific needs of particular clientele and/or sectors of industry. Bigelow Aerospace's facilities in North Las Vegas have been constructed with this in mind and the company will have the capacity to construct BA 330s on an ongoing, regular, and rapid basis.

Bigelow Aerospace also has plans to move beyond LEO, and is already working with NASA to develop concepts for leveraging private sector capabilities for human spaceflight missions to Lagrange points, Lunar orbit, or on the Moon. Bigelow spacecraft (leveraging expandable habitat technology) can be used to safely transport astronauts to a variety of destinations and as surface habitats to support future bases on the Moon or even Mars.



A model of a Lunar base with BA 330s

ATTACHMENT B

TECHNICAL ANNEX

1 Bigelow Expandable Module Communication Needs

In order for Bigelow Aerospace to successfully implement its previously described plans long-term reliability in the communications architecture will be a necessity. Past Bigelow test modules have relied on Space Act Agreements with NASA and experimental licenses from the FCC to meet the short-term goals of the programs. As Bigelow Aerospace moves into full-scale production and marketing of human-rated space stations and other spacecraft, BA requires assurance that spectrum access authority obtained from the FCC and other international partners will be viable for the extended service life spans of Bigelow systems.

The communications architecture for Bigelow Aerospace relies on the use of multiple fixed ground stations located globally to provide near continuous communications to the stations/spacecraft as they orbit (there are no existing expectations for the use of relay satellite links such as the U.S. TDRSS). The number of ground stations required and their locations are dependent on the choice of orbital inclination for any given space station/spacecraft. Bigelow Aerospace expects there to be a wide range of customers with differing needs and as such a similarly wide range of BA space station/spacecraft locations are expected over the long term. Any frequency allocation supporting Bigelow operations must consider not only FCC requirements but also be incorporated into the ITU body of regulations.

Bigelow Aerospace spacecraft will be used to support a variety of different mission scenarios. The complexity of basic station/spacecraft operations plus the needs of customer communications must be accounted for in an overall communications plan. Generally, the estimated data rates needed to support various operations are broken down into:

Telemetry	100s of kbps
Command and Control	10s of kbps
Normal Audio/Video Conferencing	from 56 kbps to 768 kbps up/down depending on quality desired
Emergency Audio	11.2 to 16 kbps
Picture Downloads	500 kbps to 1 Mbps
Compressed Video Downloads	1 to 5 Mbps
HD Live Video Downlink	5 Mbps
Customer Data Support Downlink	1 to 5 Mbps
Customer Data Support Uplink	1 Mbps
Space to Space Communications	100s of kbps

Bigelow Aerospace plans to use Shaped Offset QPSK (SOQPSK) and GMSK modulation techniques for its communication links. In order to support the initial 'Alpha

Station', BA will be requesting FCC licenses in the appropriate bands for the following uses:

Bigelow Bandwidth Requirements for the Alpha Station (comprised of two BA 330s)			
VHF	Uplink	GMSK	20 kHz
UHF	Downlink	GMSK	20 kHz
S-Band	Downlink	SOQPSK	2 MHz
S-Band	Uplink	SOQPSK	2 MHz
X-Band	Downlink	SOQPSK	10 MHz

The total number of licenses required by Bigelow Aerospace will ultimately depend on the number of independent stations and other spacecraft to be operated and their orbital geometry. Stations/spacecraft at significantly different inclinations will be capable of using the same channels without risk of interference. As more BA systems are deployed in orbit and/or other entities (domestic or foreign) launch their own space stations, additional channels will be needed to accommodate the growing bandwidth use.

1.1 Communications Criticality

Because the Bigelow stations/spacecraft will support human habitation there are variations in the criticality of the communications.

Telemetry and command and control services must be within frequency bands that have little degradation from rain or atmospheric effects. The band must allow for non-interference from other users. There must be sufficient bandwidth allocated to allow multiple space stations/spacecraft to communicate simultaneously to co-located ground stations to support events such as module dockings or stations/spacecraft in orbits that result in conjunctions or overlapping communication footprints. Typically, frequencies in the S-band range are appropriate for these functions.

The emergency audio/data backup services must be within a band that can allow for very high reliability and non-interference from other users but only needs a limited amount of bandwidth. Typically, lower VHF/UHF frequencies are appropriate for these functions.

Higher data rate functions such as video or customer data links are not as mission or real time critical such that brief outages due to local weather events or momentary interruptions can be tolerated. Higher frequencies in the X-band range are preferred.

Space-to-Space communications functions will mostly be employed during docking maneuvers and occur over relatively short range. Because these communications will

be taking place on-orbit, there are no real atmospheric concerns and very little expected interference from other users. Bigelow Aerospace believes the existing frequency bands already allocated for short-range, fixed, line-of-sight services are sufficient to meet these needs.

2 Proposed Service Designation

Historically there has been little need to distinguish in bands allocated for non-Federal Government use between regular satellite/space launch communications and human spaceflight communications. There was sufficient bandwidth allocated under the designation of "SPACE OPERATIONS" and the control of all human flight operation by the Federal Government assured that there was little risk of interference. Any harmful interference that did occur could be quickly resolved through coordination via the Federal Government interagency process. As the international use of space has increased, the frequencies designated for "SPACE OPERATIONS" and other space-related services are now being sought for use by both Federal and non-Federal users for activities that have varying levels of criticality. Communications services that have a direct impact upon the health and safety of crewed space vehicles and stations should take precedence over typical space-related communications.

With the increasing number of human flights being planned to support both private and public programs, a new service designation should be added that helps to better describe the nature of the use of an allocated frequency band. Bigelow Aerospace proposes the adoption of a service designation specifically for "HUMAN SPACE OPERATIONS," which would differentiate the allocation description from the current satellite operations services (e.g., SPACE OPERATIONS, METEOROLOGICAL-SATELLITE, MOBILE SATELLITE, SPACE RESEARCH, etc.). The new designation would be applied to applications where the communications directly affect the health and welfare of a crewed space vehicle. Bigelow Aerospace believes a better description of the use of the frequency band allocation will help in the resolution between or among primary users within the protected band of interference issues.

3 Frequency and Bandwidth Allocations

3.1 Emergency Audio/Data Backup

Emergency audio/data and backup communications links require relatively limited bandwidth allocations. Due to the criticality of these communications, however, these links need to be highly reliable and protected from interference. A minimum bandwidth of 150 kHz should be allocated for both the Earth-to-space and space-to-Earth sides of the links. This will allow multiple channels to be available to support simultaneous operations. The 399.9-400.05 MHz frequency band or the 400.15-401 MHz frequency band or the 401-402 MHz frequency band allocation should be modified to allow for both Federal and non-Federal use of the band to support HUMAN SPACE OPERATIONS (space-to-Earth) on a co-primary basis. Alternatively, a portion of the

420-430 MHz band could be carved out for this purpose. Additionally, an allocation should be made within the 148-149.9 MHz frequency band or the 149.9-150.05 MHz frequency band to allow for both Federal and non-Federal use of the band to support HUMAN SPACE OPERATIONS (Earth-to-space) on a co-primary basis.

3.2 Space Station/Spacecraft Operations Down-Link

Space station/spacecraft telemetry downlinks require a larger bandwidth to support the various activities of nominal operations. These activities encompass the telemetry communications needed to monitor equipment, nominal audio/video communications between an orbital crew and ground support, and picture/video (low def) downloads. These are core activities needed to maintain operations and ensure the safety of the crew. A minimum of 25 MHz should be allocated to support multiple channels of 5 MHz bandwidth. The 2200-2290 MHz frequency band allocation should be modified to add support for both Federal and non-Federal use of the band for HUMAN SPACE OPERATIONS (space-to-Earth) on a co-primary basis. No restrictions should be placed on the locations for receiving stations. Division of the band into multiple sub-channels of 2207-2219 MHz, 2270.5-2274.5 MHz and 2285-2290 MHz would be acceptable.

Alternatively, the Commission could modify the allocation in the 2360-2395 MHz frequency band to add support for non-Federal use of the band for HUMAN SPACE OPERATIONS (space-to-Earth) on a co-primary basis.

3.3 Space Station/Spacecraft Operations Up-Link

Space Station/spacecraft command uplinks support the complimentary activities of the telemetry downlinks. These activities encompass the commands needed to control equipment, nominal audio/video communications between ground support and astronauts, and picture/video (low def) uploads. These are core activities needed to maintain operations and ensure the safety of the onboard crew. A minimum of 25 MHz should be allocated to support multiple channels of 5 MHz bandwidth. The 2025-2110 MHz frequency band should be modified to add support for both Federal and non-Federal use of the band for HUMAN SPACE OPERATIONS (Earth-to-space) as a co-primary service. Moreover, there should be no restrictions placed on the locations for receiving stations.

Alternatively, the 1626.5-1660 MHz frequency band could be modified to add support for commercial use of the band for HUMAN SPACE OPERATIONS (Earth-to-space) as a co-primary service in part of the band.

3.4 Customer Support

Beyond the normal operations of supporting a human-rated space vehicle, frequency allocations are needed for the support of customer payloads and customer audio/video communications. While these services are not critical to the safety and welfare of the onboard crew or clients, they do require a large bandwidth allocation to support the expected data transfers from experiments and customer bi-directional communications.

The 8450-8500 MHz band allocation should be modified to add support for both Federal and non-Federal use of the band for SPACE OPERATIONS (space-to-Earth) on a co-primary basis. This would support five channels of 10 MHz bandwidth each.

In order to support customer uplink communications, there should be a corresponding allocation made for a minimum of five channels of 5 MHz bandwidth each. The 7145-7190 MHz band or 7190-7235 MHz band could be modified to add support for both Federal and non-Federal use of the band for SPACE OPERATIONS (Earth-to-space) on a co-primary basis.

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These proposals reflect the anticipated frequency allocations needed to support Bigelow Aerospace space stations and spacecraft as well as the transport vehicles that would be needed to service such systems. The proposed allocations should be sufficient for BA's needs for the initial decade of currently anticipated operations.