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INTERNATIONAL SPACE STATION (ISS) INTERNAL VOLUME CONFIGURATION (IVC)

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ABSTRACT

In the summer of 2000, only three months before the Increment 1 crew occupied the International Space Station (ISS), the ISS Program Office initiated an effort to manage the interior volume of Station as a limited resource. Various organizations in the ISS community who needed or planned to use ISS interior volume previously had no forum to communicate and negotiate their demands until the ISS Internal Volume Configuration (IVC) team and Working Group (IVCWG) were established. The IVC team operates for the ISS Program out of the Habitability and Human Factors (H&HF) branch, providing a central human/user perspective to IVC processes. All ISS Program Office organizations participate in the IVCWG.

IVC processes have been or are being developed to capture and document planned usage of ISS volume and to mitigate volume conflicts. Processes include:

- Documenting the planned ISS interior topology
- Gathering, recording and distributing planned volume demands from all ISS participants
- Documenting pass/fail volume planning criteria for crew safety and ISS productivity
- Graphic modeling of the planned ISS interior at every stage
- Graphic analysis based on the approved pass/fail criteria
- Conflict resolution
- Publication of analytical findings and results in support of ISS stage-by-stage Certificates of Flight Readiness.

While these basic processes have formed, additional efforts--political and technical--to increase the efficiency and effectiveness of IVC activity are ongoing. For example, negotiations need to occur with all ISS international partners to ensure commonality of planning processes and pass/fail criteria throughout Station.

The ISS IVC function and processes were designed late in the ISS Program's development but have proven effective even while minimizing the impact to previously existing processes and Program functions. IVC processes may have characteristics uniquely driven by the structure of the current ISS Program, but lessons learned can be drawn from them relevant to any future spacecraft design and management project.

THE IVC CHALLENGE

Despite years of planning, as of the summer of 2002 NASA and the International Space Station (ISS) Program Office do not have firm resolution on the final configuration of the ISS. NASA budget limitations place unanswered questions on Station's "Assembly Complete" definition. For budgetary purposes, a 3-person Station has been defined, but IP's and the science community are not satisfied. It takes the bulk of 3 crewmembers' time to maintain Station with little time left to conduct science. As a result, the ISS Program continually explores the benefits and ramifications of configuration options.

To assess interior "habitable" or "pressurized" volume planning configurations, the ISS Program

has engaged Johnson Space Center's (JSC's) Bioastronautics Habitability and Human Factors (H&HF) branch to create and manage an ISS Internal Volume Configuration (IVC) team. The team's functions include:

- Formally documenting planned IVC's for the Program
- Defining objective pass/fail criteria by which an IVC can be assessed
- Analyzing known IVC's using the pass/fail criteria
- Coordinating analytical results--particularly exceptions--with appropriate parties
- Resolving ISS volume and/or location conflicts among users

When the IVC team was formally established in the summer of 2000, most Station pressurized modules had been designed or built. Reconsidering the basic architecture of Station was and is not an option. All modules on ISS have a central corridor for crew activity and movement, hardware arranged between this corridor and each module's outer shell, and significant hardware/crew interfaces at the corridor-face-plane of hardware components. In all modules except the Russian Segment, hardware is typically arranged in racks of common modular size, most of which can be removed and replaced on orbit. (See Figure 1.) Within this fixed architecture the interior of Station can change, particularly since the non-Russian modular elements can be changed on-orbit, and the IVC team's essential goals are to:

1) Protect habitable volume--i.e., prevent incursion of rack- or non-rack-based hardware into the aisles and corridors of Station,

2) Protect for emergency operations--e.g., avoid blocking fire extinguishers, emergency egress paths, etc., and

3) Resolve location/volume conflicts, either:
   a. Hardware-to-hardware contact
   b. Hardware in volumes needed for crew operations
   c. Planning two or more operational volumes for use at the same time

Note that for item #3, time can be used to resolve conflicts--i.e., conflicts can be avoided by careful scheduling. For item #2, time can not be used as a factor for acceptance--i.e., emergency equipment can never be blocked.

FIGURE 1: The ISS rack-based architecture of non-Russian segments

Because the purpose of ISS' interior is to house and facilitate human activities, IVC controls are based on user/operator/human needs, making the H&HF branch a logical choice by the Program to perform the IVC function. IVC controls and their enforcement are analogous to the types of considerations and integration traditionally performed by terrestrial architects and building designers when planning shelters for human functions and facilities for user institutions.

IVC PROCESSES AND PRODUCTS

The ISS Program is organizationally divided into several functional groups. One group is responsible for building Station, another for science payloads, another for provisioning, another for day-to-day operations, etc. No one group has the responsibility of being the consolidated integrator of Station. Therefore before the IVC team began operating it was difficult for anyone planning to use a particular volume or location on Station to know if others were making plans for that same volume or location. Gathering and disseminating information therefore became a primary driver in the design of IVC processes. These processes can be explained as three sequential steps:

Step 1: Preventing hardware protrusions

Hardware protrusions are defined as those items that project out from the rack-face plane and into the aisle of a Space Station module. Hardware protrusions can interfere with crew access and operations at a rack or adjoining racks and limit crew and/or equipment translation down a module's central corridor. If hardware protrusions into the corridors of Station were completely prohibited, sufficient volume for crewmembers to maneuver and work would be assured and there would be little need for the IVC function. However, only the ISS Payload Office has established requirements limiting rack protrusions (See Figures 2 & 3) and these have been waived on several occasions. Because of the variety of science experiments planned for Station, the majority of racks designed with protrusions have been payload racks, however, some non-payload protrusions also exist. Most notably, current ISS exercise equipment--both rack-based (See Figure 4) and non-rack-based--protrudes significantly into aisles and over neighboring racks and has proven to generate the greatest number of integration issues of any category of ISS hardware.

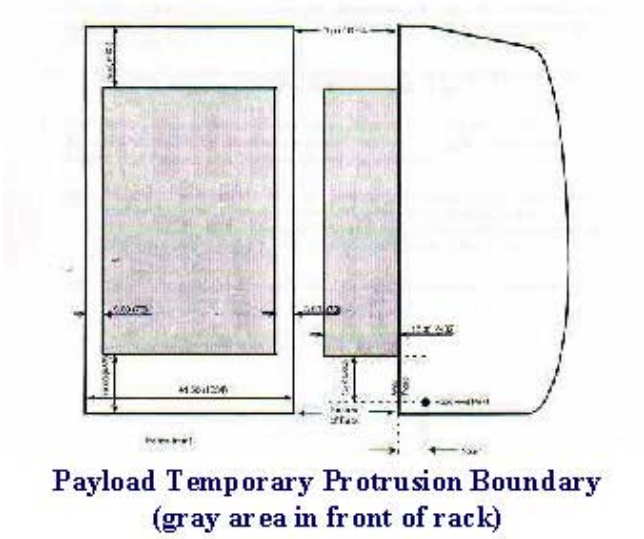

FIGURE 2: ISS Program requirements limiting payload rack protrusions

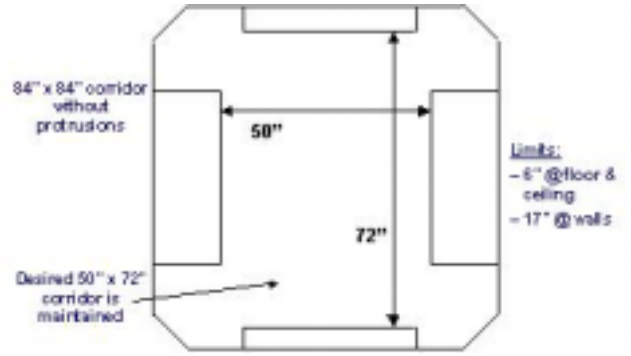

FIGURE 3: If all ISS payload racks complied with Program protrusion requirements, a corridor of 50" x 72" would be maintained in the U.S. Lab

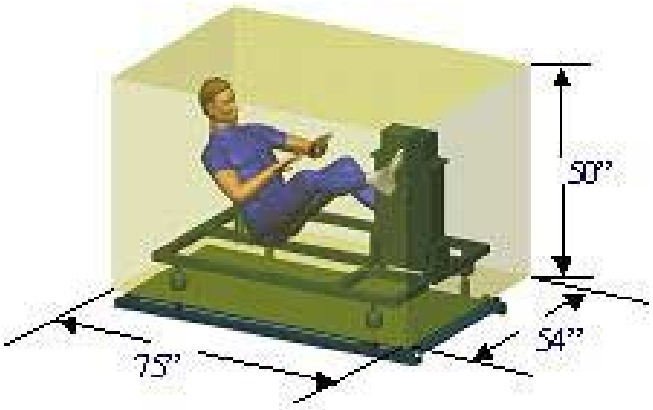

FIGURE 4: The Cycle-Ergometer with Vibration Isolation System (CEVIS) mounts to the front face of a rack. It is as wide as a rack, has a significant operational envelope (as shown), and has a dynamic range-of-motion that overlaps onto adjoining rack faces by 6.25" in each lateral direction. CEVIS is the largest rack-based protrusion that IVC has yet had to integrate.

Though the IVC team has participated in new development hardware design reviews, the team has had limited success in preventing protrusions. In fact, prohibiting protrusions altogether would seriously inhibit creativity in designing science experiments--particularly those taking measurements of human performance or requiring interaction with animal habitat gloveboxes. Preventing creative uses for Station is not the intent of the IVC team.

Therefore, bounding protrusions has come to be viewed by the team more as an effective means to require reporting on protrusions when they are first planned than as an effective tool to prohibit them altogether. This advanced planning data can then be folded into the subsequent analytical phase of the IVC process.

It should be noted that at its outset, IVC responsibility was limited to protrusions that are large--e.g., outside the boundaries of Figure 2--or that overlap into other ISS users' physical or operational envelopes. The Program decided that the IVC function would not attempt to track small crew-reconfigurable items such as portable computer workstations, crew hand/foot restraints, or cable routing. The IVC team has noted to the Program, however, that the cumulative impact of the large number of small items mounted in Station's corridors seems to be posing a bigger threat to habitable and work volume than larger pre-mission planned protrusions. IVC intends to address this concern as forward work. It's likely that processes addressing small protruding items on Station may be quite different than those outlined in this text.

In general the IVC process has focused on pre-mission planning and is not intended to limit the on-orbit crew's ability to reconfigure their environment. However, the need for establishing better feedback to the IVC of significant real-time on-orbit configuration changes has also been noted as forward work.

Step 2: Analyzing a stage configuration

Analysis determines if a particular planned interior configuration is acceptable using a Program-approved set of pass/fail criteria, the "IVC Constraints". Analysis is performed only for those re-supply missions adding or removing a significant complement of ISS interior components. ISS configurations resulting from major interior modifications are called "stages".

Analysis consists of:

- Understanding the flight manifest sufficiently to identify significant IVC stages--i.e., which flights/stages require analysis
- Modeling the planned IVC for significant IVC stages using 3-dimensional (3-D) computer-assisted design (CAD) (See Figure 5.)
- Identifying potential conflicts where overlaps exist between documented volume demands and the IVC Constraints (See subsequent sections and the Appendix for further data on the Constraints.) (See Figures 6A and 6B.)
- Documenting the IVC Constraint "exceptions" within the Program and grouping them into categories based on IVC team rationale for acceptance or rejection

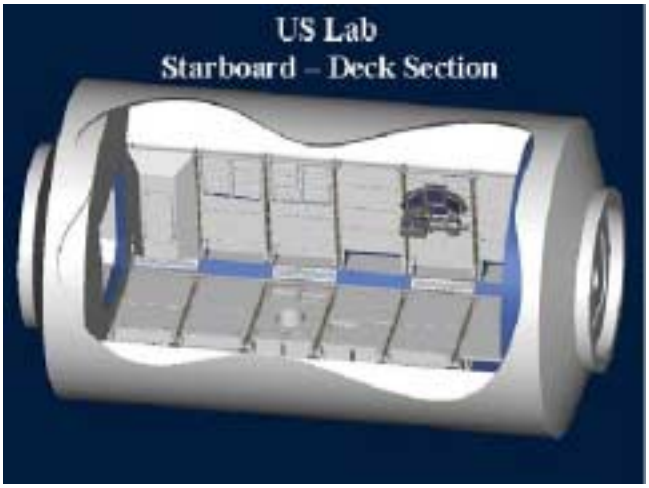

FIGURE 5: An IVC CAD model of the U.S. Lab at a particular stage configuration

FIGURE 6A: U.S. Lab CAD model with IVC Constraints superimposed

FIGURE 6B: "Donut slice" of U.S. Lab CAD model with IVC Constraints superimposed. Such close-in views are typically used to illustrate problem areas where volume demands conflict

Step 3: IVC Verification

The final product desired by the ISS Program from the IVC process is a statement that a particular stage is acceptable and "ready for flight". Information on the IVC integrates with other system acceptance data into a top Program level Certificate of Flight Readiness (CoFR). The H&HF IVC team manages a Program-chartered IVC Working Group (IVCWG) that determines if exceptions can be justifiably accepted and then makes a final CoFR recommendation for every significant IVC stage. This step of the IVC process takes the results of graphic analysis and determines the fate of exceptions among ISS Program representatives in as repeatable a manner as possible.

In developing each step of the IVC process, consistent repeatability was a primary concern. The IVCWG wanted to minimize the inconsistent influence of individual member organizations, personalities or attendance and did not want to meet after every stage analysis to debate each IVC exception. The H&HF IVC team has identified as many as 30 IVC Constraint exceptions per stage. How then to promote consistency of IVCWG judgment when reviewing so many exceptions?

The H&HF core IVC team promotes stage-to-stage consistency by channeling initial exception review responsibility to those parties most affected by particular types of IVC Constraint violations. As experience with graphic analysis matured over several ISS assembly stages, categories into which exceptions could be divided became obvious. These include (but are not limited to):

- Conflicts that can be resolved by scheduling. Because of many associated variables, time-dependency was not written into the IVC Constraints but was left for resolution in this more political step of the IVC process. Since the IVC/IVCWG is a volume and/or location based activity, scheduling exceptions are passed to a different working group who review and respond to the IVCWG if all scheduling (and therefore associated volume) conflicts can be prioritized and resolved. The majority of operational volume conflicts are resolved simply by scheduling the tasks involved at different times.
- Constraints associated with a particular ISS subsystem. For example, more than any other IVCWG member, it is important for the Environmental Control and Life Support System (ECLSS) team to determine if they can accept more airflow blockage of their vents than allowed in the ECLSS section of the IVC Constraints.
- Constraints traditionally managed by a particular responsible organization. For example, the ISS Safety team has primary Program and JSC institutional responsibility to confirm that planned configurations do not block ISS emergency response equipment or escape corridors.

To avoid future misunderstanding among the IVCWG, the H&HF IVC team has documented and sought member signature concurrence on the identification and roles of review teams with primary exception assessment responsibility. IVCWG members continue to collectively review a final stage verification report, but since consistent review processes and responsibilities have been established, final modifying comments are not common.

In the event the IVCWG cannot justify accepting an IVC Constraint exception, the IVCWG is chartered to take the issue or conflict to higher-level ISS Program boards for formal Program

resolution. Program management has the expectation, however, that the IVCWG will have made every effort to resolve conflicts by either 1) modifying hardware designs, 2) revising the ISS topology, or 3) changing the ISS manifest--i.e., re-scheduling arrival or departure of conflicting items. Chances of successfully implementing any of these paths are directly proportional to the amount of time available before a planned launch. Therefore it is imperative that the entire IVC process is executed as strategically ahead of planned flight dates as possible. Since its inception the H&HF IVC team has strived to accelerate the schedule for analyses with a minimum target date of Launch-minus-16-months for an IVC stage analysis baseline. Analyses baselines of Launch-minus-3-years are believed possible, however, these will need periodic updating as more accurate IVC information becomes available during mission planning and hardware construction cycles.

Through the use of relatively simple graphic-based IVC Constraints, of consistent configuration-managed models reflecting ISS interior components, of repeatable graphic analysis techniques, and of focused review responsibilities a functional, cost-effective method for ISS internal volume management has been established. Issues and concerns with the IVC process are discussed in the following sections.

IVC CONSTRAINTS

The IVC Constraints are documented in the ISS Program Generic Groundrules, Requirements, and Constraints (GGR&C) document. Excerpts are included in the Appendix.

The IVC Constraints document the volume needs or demands of various ISS systems and operations. They are graphic, specific definitions of volume, designed expressly to support repeatability in IVC graphic analysis. Using the Constraints along with configuration controlled interior CAD models verified to ISS measured drawings, different CAD analysis teams should derive identical sets of IVC Constraint exceptions.

When the IVCWG membership reached agreement on the IVC Constraints, the first test for IVC acceptability was effectively defined--i.e., only areas of overlap where exceptions are generated require closer scrutiny of the IVCWG. Because of the complexity of any living and working environment as tightly contained as that of ISS, no manageable set of rules can cover every combination of circumstances--e.g., what defines a protrusion, the scenario under which an item protrudes, the criticality of the task the protrusion supports, etc. Therefore the IVCWG agreed early on to use the IVC Constraints as screening criteria to identify areas of interest rather than as the final word on assessing pass or fail of a particular integrated IVC.

Not all graphic IVC Constraint overlaps produce exceptions. Constraints requiring free volume can overlap without conflicting with each other--e.g., crew & equipment translation corridors, unobstructed volume in front of emergency equipment, and free volume in front of air outlets.

Some Constraint graphic overlaps are seldom acceptable--e.g., hardware hitting hardware--whereas others may be deemed acceptable because they are minimal violations or can be managed with operational workarounds such as careful scheduling.

A long-range goal of the H&HF IVC team is to automate the graphic analysis process so that the acceptability of any new stage configuration can be quickly determined. Such a tool--potentially accessible and operable online--would be a powerful planning tool for those defining future ISS manifests and/or rack topologies. Since the IVC Constraints are essentially unchanging, all one need enter would be a planned rack-by-rack topology. Information on each of the racks would need to be included. Unique or new pieces of hardware would require modeling.

Within a year, the IVC team hopes to have the results of strategically performed ISS Assembly Sequence stage analyses on-line so that developers planning use of ISS' interior volume can be better informed of planned IVC's. Various means of graphically displaying this information

online are currently under review. The technical ability to support an operator-driven fly-through is being explored.

Though to a large degree the formats of the IVC Constraints and graphic stage analyses may enable future automation, their design also imposes certain limitations. By design, the IVC Constraints and analysis process generates exceptions that demand "manual" review and judgment. Three other limitations of the current process are particularly noteworthy:

- Constraint tolerances can't be documented. In the Program culture, defining a translation corridor width as "32 inches ±2 inches" is equivalent to defining it as "30 inches". There is no process for rewarding adherence to the original and desirable width and no penalty for using the maximum tolerance. During analysis several 1 or 2 inch incursions into work volumes are typically exposed and must be documented as letter-of-the-rule exceptions. There is seldom proof that such minor incursions into work volume will cause difficulty and the exceptions are typically approved. After all, it must be acknowledged that several boundary limits in the IVC Constraints are somewhat arbitrary. However, in order to make the process function, "lines in the sand" had to be drawn somewhere. The resulting minor violation exceptions will continue to require review team evaluation on a case-by-case basis.
- The Constraints only minimally reference time. The largest category of Constraint exceptions includes items that can be evaluated against time. Two items may appear to conflict in the IVC graphic analysis but in reality will never be scheduled to deploy or be operated at the same time. The Constraints might have been written to include more information about time, but quite often this information isn't readily available even at launch. Ground planners do not have the same insight into long-duration mission planning as they do for highly choreographed short-duration missions. Too, the IVCWG does not have any political control over mission scheduling. The IVCWG's domain is strictly volume and/or location. Perhaps in the future an automated IVC planning tool could be integrated with time planning tools, but there are no current plans to consider this. As it stands, the IVCWG identifies potential physical or operational conflicts and supplies the data to schedulers who create rules to avoid planning these scenarios.
- The GGR&C does not lend itself to frequent changes, including the incorporation of short-term "lessons learned". This relates to both of the examples above. For example, on a stage analysis the IVC verification process may determine and document that a 2" incursion into an ISS translation corridor is acceptable. There is no means available to modify the impacted IVC Constraint to accept this condition for the next "x" number of flights. Each subsequent stage analysis will identify the same exception and require it to be processed for acceptability by review teams. This is a noteworthy aspect of the IVC Constraint and analysis process, but not necessarily a negative one. It forces the IVCWG to remain aware of less than desirable conditions on Station.

IVC LESSONS LEARNED

Following are additional insights into the benefits and limitations of the current state of the ISS IVC process:

- The IVC process came along very late in the design of the ISS, long after the architecture of Station was defined. A much more comprehensive internal configuration process could have been defined earlier in the Program with authority over architecture, topology, manifesting, etc.
- Processes for an IVC function with more comprehensive authority might be very different than the current IVC process.
- The diffusion of political responsibility within the Program has negatively impacted the design of other Space Station integration processes that should have had a stronger human factors central thrust. Of particular note is that there were never requirements for commonality of crew interfaces on Station.

- At the time of the IVC's inception, many political turfs had been staked out. The IVC function had to be designed to interface with many other processes and only minimally impact them. Of particular note:
  - Though some of the IVC Constraints specifically mention non-standard stowage--i.e., stowage in the corridors of Station--the IVC team has no controlling authority over, advisory position to or information on the on-orbit planning of stowage. The IVC team believes it is forward work to close this gap within the Station Program by integrating or at least sharing planning information between stowage and IVC.
  - By Program agreement, the IVC has no authority over or insight into the Russian Segment. IVC would like to at least share planning information and may pursue this if a process can be established that will not incur cost.
  - IVC information on ESA and NASDA module interior planning is unresolved. This is documented forward work for the IVC team to pursue.
  - The IVC process only supports pre-mission planning of Station's interior. The IVC Constraints do not apply to the crew's real-time on-orbit configuring of their own environment. To a large extent this is as it should be--i.e., the on-orbit crew should have the freedom to control their environment. At times, however, ground controllers have had to supply configuration information equivalent to the IVC Constraints to the on-orbit crew to ensure safety critical equipment remains accessible.
  - There is currently very little feedback mechanism for improving IVC tools based on video or other data from Station's true on-orbit configuration. The IVC team may explore possibilities and potentials for integration with Station real-time monitoring and operations.
  - The IVC function was directed to exclude many small crew-reconfigurable items on Station--e.g., laptop computers, crew restraints, etc. For the most part the IVC team would have difficulty tracking the location of these items and there is very little reason to do so. However, the IVC team has noticed that the accumulation of some small items--notably untethered cables and hoses--poses a potentially bigger impact to working volume on Station than larger hardware items.
  - Manifesting data on ISS payloads is an input to the IVC team. The IVC team is not actively consulted during manifesting decisions. Since altering manifests is one means of resolving volume/location conflicts, IVC may become more proactive in payload manifesting processes.
  - Other Station manifesting processes--e.g., for small and loose equipment--currently have no interaction with IVC. This may be reconsidered if the IVC begins to address the accumulation of small equipment and non-standard stowage.
- Within given constraints the H&HF IVC team has successfully designed and implemented a function that addresses one type of ISS integration planning issue--volume and location conflict--and that contributes to improving human performance on Station.
- The IVC team has developed tools and processes that could accomplish more if the Station Program agrees to do so. Budgetary constraints are a strong concern in the Station Program. However, the IVC team may assume additional responsibilities within current budget constraints due to flexibility designed into IVC processes and tools.

CONCLUSION

The Internal Volume Configuration team at JSC has established processes for human factors based control of ISS interior planning. Planning constraints on volumes have been defined to protect crew working and living needs, equipment demands, and emergency equipment and egress access. These planning constraints are tested against computer models of ISS' planned interior configurations and exceptions

are processed within the Internal Volume Configuration Working Group (IVCWG) to support a Certificate of Flight Readiness confirmation that the planned interior configuration supports ISS mission objectives. The IVCWG performs its work sufficiently in advance of ISS flight dates to allow issues to be worked while there is still time.

Although not the most comprehensive or ideal way to bring internal volume control to a complex vehicle, the IVC team has established a functional process within a framework of political, budget and pre-defined architectural constraints. IVC processes promote communication among planners, impose limited impacts to existing ISS Program processes and are flexible enough that they may be expanded in the future to include IVC areas and issues not currently addressed.

The set of constraints and types of graphic analyses that shape ISS IVC processes may be too unique to the Station Program to be applicable verbatim to other interior configuration processes. However, the processes of defining acceptance pass/fail criteria and of testing those criteria against computer models of planned configurations may have universal applicability. Of particular note is that IVC pass/fail criteria are primarily based on human/user considerations, not on purely structural or mechanical systems demands. Planning and integration of living and work volumes based on human/user needs could well be one way of defining “architecture”.

REFERENCES

NASA-STD-3000 / Man-Systems Integration Standards

SSP 50005 / International Space Station Flight Crew Integration Standard (NASA-STD-3000/T)

SSP 50261-01 / Generic Groundrules, Requirements, and Constraints, Section 3.12, “Internal Volume Configuration (IVC) Constraints and Groundrules”

SSP 50564 / Internal Volume Configuration Document [published by the IVC to formally document ISS’ planned interior configurations]

ACKNOWLEDGMENTS

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DEFINITIONS, ACRONYMS AND ABBREVIATIONS

GGR&C: Generic Groundrules, Requirements & Constraints document, ISS Program. A collection of operational era controls on Station planning and/or operations

H&HF: Habitability & Human Factors branch of the Bioastronautics Office at Johnson Space Center, Houston, Texas

IVC: Internal Volume Configuration

IVC team: The core group of individuals comprising the Bioastronautics Office Habitability and Human Factors IVC team at JSC

IVCWG: IVC Working Group. An ISS Program Office chartered collection of members from every primary Program Office division, plus JSC Safety, Mission Operations, the Crew Office, and Bioastronautics

APPENDIX

Following are excerpts from SSP 50261-01, Generic Groundrules, Requirements, and Constraints, Section 3.12, "IVC Constraints & Groundrules". Note that all GGR&C IVC Constraints include supporting rationale that is not included here.

3.12 INTERIOR VOLUME CONFIGURATION

The constraints and groundrules of this section apply to pre-mission planning of the integrated interior volume. These constraints and requirements are not intended to constrain the on-orbit crew from configuring their environment but are developed to aid in the planning process and required documentation to ensure a safe and habitable environment.

3.12.1 CREW TRANSLATION PATHS

3.12.1.1 LABORATORY MODULES

The unobstructed crew translation path between hatches and hatch vestibules in the U.S. Lab shall be a minimum 50 inch x 72 inch (127 cm x 183 cm) rectangular passageway. The unobstructed extruded rectangular volume may bend and curve along the length of the module.

This constraint shall apply to the integrated interior environment, including hardware protrusions and non-standard stowage planned to occupy or protrude into habitable interior volume. The crew translation path may be encroached upon by operating volume for crewmembers at worksites and by maintenance operations. The crew translation path may also be encroached upon by momentary protrusions, though no integrated combination of momentary protrusions shall leave less than a minimum unencumbered emergency translation path of 32 inches by 45 inches (81 cm x 114 cm).

3.12.1.2 NON-LABORATORY MODULES

These constraints shall apply to the integrated interior environment, including hardware protrusions and non-standard stowage planned to occupy or protrude into habitable interior volume.

a. Nominal Crew Translation Path: The unobstructed crew translation path in applicable non-laboratory modules between hatches and hatch vestibules shall be a minimum passageway of 32 inches by 72 inches (81 cm x 183 cm). The unobstructed extruded passageway may bend and curve along the length of the module. This volume may be encroached upon by momentary protrusions, operating volume for crewmembers at worksites, and maintenance operations. (See Figure 3.12.1.2-1.)

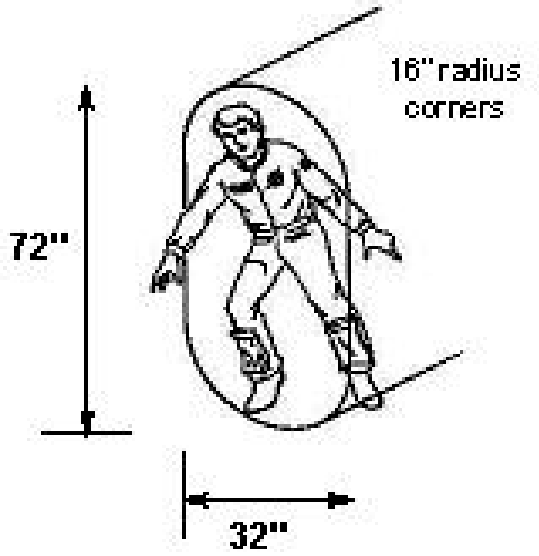

FIGURE 3.12.1.2-1 MIN. NOMINAL TRANSLATION PATH DIMENSIONS, ONE CREWMEMBER IN LIGHT CLOTHING

3.12.2 CREW WORKSITE OPERATIONAL VOLUME

At all locations where crew operations of more than 20 minutes duration are planned, adequate volume must be provided for crewmembers. Maintenance operations are excluded from this constraint.

3.12.2.1 GENERIC RACK-BASED WORKSITE

At U.S. On-orbit Segment rack-based crew worksites the volume to be reserved for crew operations shall be 36 inches deep (from the face of the rack) by 41 inches wide (centered on the rack width) by 76 inches high (91 cm deep x 104 cm wide x 193 cm high), as shown in Figure 3.12.2.1-1. The center of the 76 inch height of the operational envelope can be located ±5 inches relative to the center of the 74 inch height of the rack. For racks with worksite protrusions--e.g., gloveboxes--that require crewmember operators to be nominally positioned further away from the plane of the rack face, the crew worksite volume of Figure 3.12.2.1-1 shall be adjusted outward from the plane of the rack face accordingly. Approved hardware protrusions may extend into the crew worksite volume but shall not impede the operator from assuming the configuration needed to perform all nominal worksite operations. If no hardware protrusions are present the rack-based crew worksite volume may overlap with crew and equipment translation paths.

Rack-based worksites will not always align with a module's local vertical. It is possible for rack-based worksites to be installed in the deck or overhead surfaces of a module. Worksite operational volumes shall not conflict with each other unless it can be demonstrated by analysis that the conflicts are preventable by time phasing operations or other operational means.

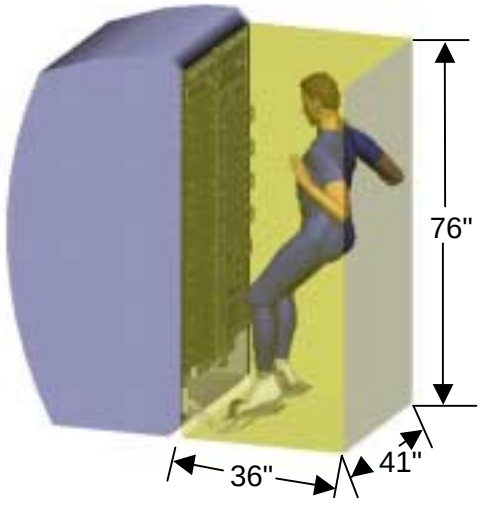

FIGURE 3.12.2.1-1 GENERIC RACK-BASED CREW WORKSITE VOLUME

3.12.2.2 UNIQUE RACK-BASED WORKSITES

b. Crew Health Care System (CHeCS) Rack #1: CHeCS Rack #1 contains emergency critical items. No equipment shall be deployed over the face of the CHeCS rack for any period of time. The generic crew worksite volume of 36 inches deep by 41 inches wide by 76 inches high (see paragraph 3.12.2.1) (91 cm deep x 104 cm wide x 193 cm high) shall be reserved for use of CHeCS Rack #1.

3.12.2.3 NON-RACK-BASED WORKSITES

a. Interim Resistive Exercise Device (IRED): A clear volume of 60 inches (152 cm) (forward to aft) by 50 inches (127 cm) (port to starboard) by 80 inches (203 cm) (zenith to nadir) shall be reserved for crew operations at the deployed hard-mounted IRED. This rectangular volume is centered on and resides above the IRED foot plate in the direction of a standing operator. (See figure 3.12.2.3-1.)

The IRED operational volume shall not conflict with other operational worksite volumes unless it can be demonstrated by analysis that the conflicts are preventable by time phasing operations or other operational means.

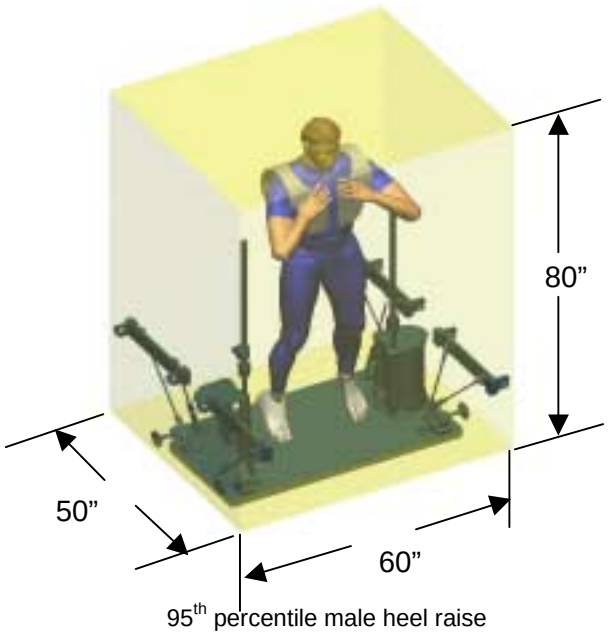

FIGURE 3.12.2.3-1 HARD-MOUNTED IRED OPERATIONAL ENVELOPE

c. Cycle Ergometer with Vibration Isolation System (CEVIS): A clear volume of 75 inches (190 cm) (centered over CEVIS, front-to-back) by 55 inches (140 cm) (centered over CEVIS side-to-side) by 50 inches (127 cm) high (as measured upward from a plane 6.5 inches below the bottom of CEVIS' structural frame, not including the isolators or their attachment fittings) shall be reserved for crew operations at the CEVIS location. (See figure 3.12.2.3-2.)

The CEVIS operational volume shall not conflict with other operational worksite volumes unless it can be demonstrated by analysis that the conflicts are preventable by time phasing operations or other operational means

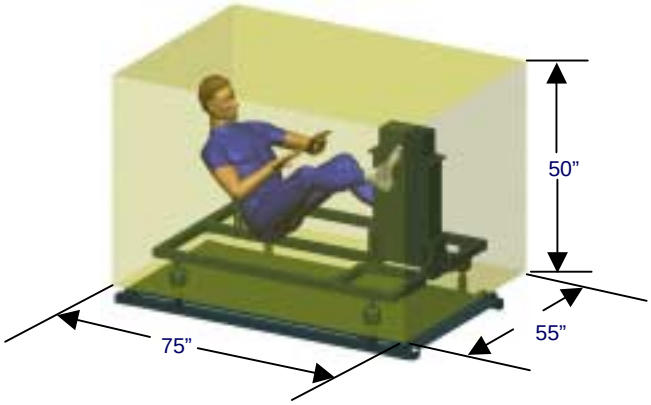

FIGURE 3.12.2.3-2 CEVIS OPERATIONAL ENVELOPE

3.12.3 VISIBILITY AND ACCESS TO CRITICAL EQUIPMENT AND CONTROLS

A clear, unencumbered volume shall remain free at all times of hardware protrusions and non-standard stowage in front of safety critical and/or emergency equipment and controls requiring crew physical or visual access. Safety critical and/or emergency equipment and controls include any piece of gear used by the crew to detect, combat, protect, annunciate, or otherwise alert against an ISS emergency. Clear volume geometries in this section must be modified as needed to conform to unoutfitted module design configurations and to the configuration of approved hardware protrusions.

Safety critical equipment and control clearance zones shall include but not be limited to:

1) A clear volume described by the frustum of a 30 degree cone with its smaller terminal diameter centered at and encompassing the critical control (See Figure 3.12.3-1). The frustum shall be the longer of 28 inches (71 cm) or the length required to intersect a module's crew translation paths. The frustum shall be reserved perpendicularly in front of:

- ISS vehicle subsystem Caution & Warning (C&W) indicators (e.g., LEDs)
- Rack-unique C&W indicators
- Audio Terminal Units (ATU)
- Fire detection indicators
- Rack power switches (also called rack maintenance switches)
- Portable Breathing Apparatus (PBA) O_2 ports
- Emergency and Caution & Warning labels

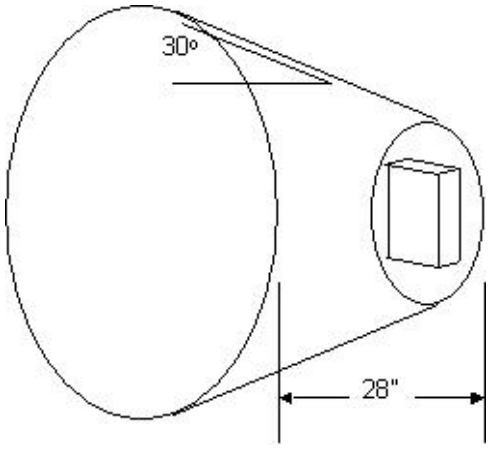

FIGURE 3.12.3-1 CLEARANCE ZONE FOR LOCALIZED CRITICAL CONTROL

3) A 24 inch (61 cm) long and 12 inch (30.5 cm) wide rectangular clear volume (See Figure 3.12.3-2) shall be reserved at one end and in front of:

- PFE fire suppression access ports

The volume shall be the deeper of 28 inches (71 cm) or as required to intersect a module's crew translation paths.

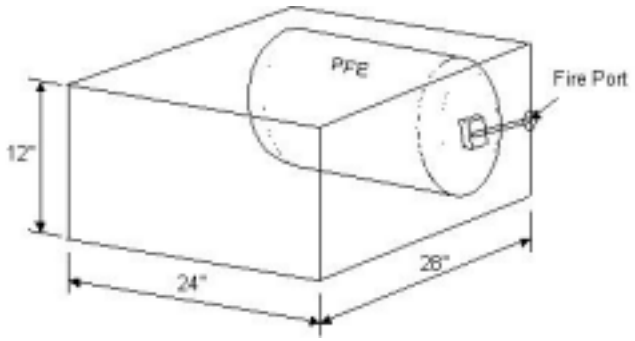

FIGURE 3.12.3-2 CLEARANCE ZONE FOR PFE AT A FIRE PORT

3.12.5 LIGHTING

The operation and effectiveness of light sources shall not be encumbered by hardware protrusions or non-standard stowage.

The following clearance zones shall be reserved:

1) A clear volume described by the 28 inch (71 cm) deep frustum of a 30 degree cone with its smaller terminal diameter centered at and encompassing the lighting controls (Reference Figure 3.12.3-1) shall be reserved perpendicularly in front of lighting controls.

3.12.6 ECLS SYSTEM

Airflow and the operation of ECLS equipment shall not be impeded by hardware protrusions or loose equipment. Permanent structures (hardware attached to the pressurized hull prior to launch and remaining attached, including standoffs and endcone panels, Node midbay panels, UOP's, lights and hatches) and standard racks not having protrusions are excluded from ECLS constraint applicability. Where needed for airflow passage, the reserved volumes shall be extended to reach into continuous clear zones such as crew worksite volumes and translation paths.

3.12.6.1 NODE 1

The following clearance zones shall be reserved:

a. A two foot (61 cm) radial clearance from the following devices shall be reserved. The devices shall not be covered. The two foot (61 cm) radial clearance shall be measured from all outer perimeters of the device.
   - Diffusers (Air Outlets)
   - IMV grilles

b. A one foot (30.5 cm) radial clearance from the following devices shall be reserved. The devices shall not be covered. The one foot (30.5 cm) radial clearance shall be measured from all outer perimeters of the device.
   - Returns (Air Inlets)
   - Smoke detectors
   - Sample delivery probe

c. A six inch (15.25 cm) diameter clearance around the following devices shall be reserved. The devices shall not be covered. The devices shall be accessible by the crew.
   - Pressure equalization valves
   - PBA O_2 QDs
   - IMV valve manual overrides
   - RAMV position switches