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PSYCHOLOGY OF SPACEFLIGHT

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 Chapter 7 from *Human Spaceflight Mission Analysis and Design*

The high costs and constraints involved in placing humans in space make people the most important "subsystem" within a mission. Flight experience worldwide shows that if we don't protect and get the best from this critical subsystem we may threaten the mission's goals, risk the health of the crew, and invite a wide variety of very unpleasant and unnecessary mission headaches. We have the technology to address psychological issues and greatly increase the probability of mission success. This chapter introduces the basic concepts and factors we should consider in a generic mission, but I won't detail procedures about the psychological selection, training, inflight support, and monitoring of crewmembers.

Space programs in the United States, Russia, and Europe have had considerable experience with the effects of psychological issues on space missions. Three lengthy Russian missions reportedly ended early in part because of psychological difficulties among the crew [Goncharov, 1994]. Soyuz 21 (1976) completed 49 of the planned 54 days before interpersonal issues among the crewmembers became untenable. Soyuz T-14 (1985) completed 56 days of its 216-day mission, during which mood and performance difficulties combined with medical issues to force the curtailment. Soyuz TM-2 (1987) was the first lengthy Mir mission; interpersonal issues played a role in the decision to end that flight after 6 of the planned 11 months. The crew of Skylab III (1974) expressed their displeasure about their excessive workload by diverging with ground control and interrupting work. The first flight of the joint US-Russian space program on Mir 18 (1995) witnessed many psy-

chological events, and the US crewmember declared that psychological issues are the most crucial ones affecting lengthy missions.

Each of these more noticeable events represents a host of others. For example, the seven joint US-Russian Mir missions experienced widely varying psychological events and conditions, including the death of a crewmember's parent and accompanying bereavement, resentment, and social disruption among the crewmembers. Mixed cultures and genders added tension, as did varying abilities in Russian and English. The crews also had to deal with extreme work underload and overload, sleep deprivation, an on-board fire, a collision and complete depressurization of part of the station, chronic thermal and atmospheric problems, plus a long delay for a return flight. Among the negative events were oral outbursts, friction between crews and people on the ground, depression and demoralization, guilt, fear, burnout among ground teams, motivation drops, cardiovascular arrhythmia and other physical manifestations of stress, reduced short-term memory, and mission-significant errors in completing tasks.

Among the many positive psychological events, we can note a strong sense of personal accomplishment and achievement, meeting and surpassing the technical and scientific expectations for a mission, establishing strong friendships among crewmembers and people on the ground, showing humor and close camaraderie, volunteering to help others during work, and sharing fresh food and stories of home. They also showed determination and mutual support during hardship. Not every psychological event or mood is important to the outcome of a mission, but the more significant ones affect goal attainment, individual health, motivation, team performance, and whether people remain with their organization

after the mission. Attending to people during the design phase will greatly decrease negative outcomes and increase positive ones.

Over an extended mission, the environment and structure of activities begin to influence attitudes, behavior, performance, and health. Stressors from multiple sources can be overt (from events) or latent (from, for example, the tedium of certain activities). The latter are often the most difficult to deal with because we usually detect them only from their "wake effects." Of course, once we detect the wake, the ship has passed, so prevention through good design is the order of the day.

Many good texts and reviews address stress, how to measure it and how it affects performance, team functioning, and health [Svenson and Maule, 1993; O'Hare and Roscoe, 1990].

7.1 Basic Concepts

As with engineering systems, the main purpose of psychological design is to accomplish mission goals and deal with environmental demands in the most effective way. Psychological design objectives aim to attain specific goals in health, well-being, and performance readiness. Several basic concepts are important to successful design.

Concept #1: Strong linkage to mission goals. Once we've formed the broad mission concept, the target mission's objectives and characteristics drive design activities for psychology. We must tightly link our goals for the crew's health, well-being, and performance readiness to the mission's overall goals. This linkage must be apparent or demonstrable to others within the organization to ensure the activities have enough support to survive the difficult design trades that accompany the implementation process. If the linkage is clear to the designer, but not to others, it will fail.

The Goal Attainment Model (Fig. 7-1) presents a way to think about general relationships between mission goals and our strategies and tools for psychology. This is not a scientific model but instead is a conceptual structure in which specific linkages can be presented. Using this goal model gives us at least four advantages:

1. It is consistent with the goal-driven environment of a mission-oriented organization.
2. It is intuitively understandable to astronauts and operational people at all levels.
3. It directs attention to how psychological activities and tools can contribute to the mission success.
4. We can use it to assess the effectiveness of the countermeasures by establishing simple metrics for each box and

Fig. 7-1. The Goal Attainment Model. We can use a goal-based model to guide the design and implementation of optimizing procedures and countermeasures. The use of goals throughout the model provides a basis for operational measurements of effectiveness and a method of describing the linkage between the procedures and the mission goals. The psychological design process begins with the mission goals and works down the tree toward the tools needed to achieve them; during implementation, the effect of the tools on mission success is exerted upward through achievement of the intervening goals.

determining how the countermeasures help achieve operational goals.

Clearly, particular behaviors are required to achieve particular goals, and a number of variables intervene between our strategies and countermeasures and the lowest level of psychological goals. Still, the model is a good summary template for design purposes.

In Fig. 7-1, the design mandate flows from top down, and the implementation effects flow from bottom up. From the top down, we're concerned with the overall mission's success, such as meeting certain objectives for exploration and science. This success depends on effective functioning of the crew's members, the crew as a whole, and the larger team consisting of the crew, ground controllers, and mission management. Formal and informal benchmarks for "effective functioning" at this level may be explicit or may exist within an organization as unstated performance expectations. The extent to which goals are reached here depends in turn on the more specific factors shown: the psychological health and well-being of the individual crewmembers, the extent to which crewmembers can and do perform their solo mission tasks, the extent to which crewmembers can and do perform interdependent tasks with one another and with the ground, and the quality of the relationships and work climate within the crew, within the ground teams, and between the crew and ground personnel. These are behavior and performance goals. Goals in these areas determine the choice, development and crafting of the specific strategies and countermeasures (e.g., selection procedures, training content, in-mission support methods, etc.) which affect them. The strategies and counter-measures are the tangible products of the psychological design process.

Concept #2: Prevention and optimization. Psychological designs try to prevent psychological or performance dysfunction in crewmembers, the crew as a whole, and those parts of the ground team most closely involved in mission operations. They also try to

enable the best psychological health, well-being, and performance among all these. Many things influence a mission's success, but it's always better to prevent problems with a careful psychological design than to try to solve them during a crisis. Psychologists do about 80% of their work before a mission begins.

If we design and implement effectively, the mission will roll out with fewer problems, and we can stay in the background during the flight. Once the mission is under way, we'll have less communication, less powerful interventions, and less control over important mission-shaping factors.

Concept #3: Integrated systems approach. As the model in Fig. 7-1 indicates, we can't effectively influence mission goals without addressing the role of the wider organization. An integrated systems approach addresses not only each astronaut but also the influence of the astronaut's family, the crew climate, relationships with the ground, and so forth. This approach steers us toward a particular array of interventions. When thinking of psychological activities, some may picture a bearded psychoanalyst inquiring about the inner soul of an astronaut who is lying on a leather couch. Besides the stereotypical imagery, this view suffers from two inaccurate assumptions: (1) the main source of emotional, cognitive or performance problems is the astronaut having those difficulties, and (2) therefore the key to preventing or resolving those difficulties is to focus on and possibly "fix" the astronaut. Traditional clinical approaches to such difficulties reinforce that stereotype. In designing for space missions, however, we must take a broader view.

The psychological state and functioning of each crewmember are certainly critical. But difficulties often arise from, or are related to, (1) organizational conditions such as poor policies or decisions, confusing procedures uplinked, or insufficient time off before and after a flight begins; (2) the flight environment such as limited communications and inadequate equipment or information; or (3) the crew as a whole, such as work norms, leadership styles, or job roles. To design effectively, we must consider these system influences.

Concept #4: Linkages and knowledge. An operational psychology group that plans and carries out a mission has to link with an unusually large number of other technical groups and stakeholders in the mission. Psychological issues and the methods by which they are addressed typically span an organization's traditional boundaries and require active participation and support from diverse groups. For example, we have to establish internal links with the astronauts' office management, the mission's program management,

the crewmembers and their families, research psychologists, and people working with flight training, communications, medicine, and mission control. We must have external liaisons with key people in academia, for new and emerging research findings; with psychologists in the civil and military organizations who have techniques or experience in missions like the target one; and with psychological counterparts in other international space agencies that have relevant experience or are contributing astronauts to the mission.

Knowledge of the target mission's environment and the people who will be living and working in it is essential for good design. Psychologists should spend some time living and working under conditions similar to those of the target mission. Also, linking to operational psychologists in other organizations who work with similar missions or people will give us a lot of pragmatic design knowledge and tips. In this way, we'll learn about the mission's realities, constraints, and possible countermeasures. If possible, psychologists should share some tasks, office space, social time, and so forth with the astronauts. Since the purpose of design is to ensure that the astronauts have a successful mission, we must understand their priorities and concerns. We'll gain this access only if we can establish and maintain trust and if we offer practical tools and information that will help the crew achieve their mission goals.

7.2 Designing the Psychological Aspect

In designing for psychological issues, we begin with the early mission concept and continue until psychological requirements and countermeasure strategies are levied on the mission (Table 7-1). It is an exceptional opportunity to be included in development of the early mission concept from the beginning. An example of this on Earth was the series of long-duration chamber tests at NASA's

Step	Questions	Key Issues	Reference
1. First Check	Is the early mission concept reasonable for humans? Is it feasible to maintain health, well-being, and performance?	General mission goals, duration, vehicles/habitats, crew complement, overall preflight and in-mission timeline, communications, etc.	Chaps. 2, 6 Sec. 7.4.1, 7.5
2. Determine mission demands	What are the specific expected values of the driving mission factors (pre-mission, in-mission and post-mission) that most influence goal attainment? What scenarios might occur that would be most stressful? What specific psychological demands does the target mission levy on the individual, the crew, and the families?	Duration (transit and emplaced), social density, personnel characteristics, work/rest characteristics, crew autonomy, preflight and postflight timelines; crew experience, maturity of planned procedures, characteristics and constraints of all communication venues; specific environmental characteristics, critical scenarios	Sec. 7.4.2, 7.4.3, 7.5
3. Access knowledge base	What has already been done and learned before in this area? What is most relevant to the target mission and the driving factors? How reliable is the information? What do we not know?	Previous mission documents, discipline experts, experienced personnel, scientific and applied literature	Sec. 7.4.4, 7.5
4. Detail countermeasure tools and strategies	What specific methods and capabilities are needed to maximize goals and maintain health, well-being, and performance? What related tools and procedures must we use to best achieve goals? What constrains our best design?	Highly specific activities and procedures directed toward: • Preflight • In-mission • Postflight	Sec. 7.4.6, 7.5
2. Develop requirements	What conditions and countermeasures are essential? What crew time and other resources are required of the organization?	Provide enough detail (frequency, functionality) for implementation	Sec. 7.1, 7.2, 7.3, 7.4.5, 7.5
3. Levy the design	What local activities are necessary to assure that the design is fully implemented?	Fully document countermeasures and requirements; continually exchange information with implementing groups	Sec. 7.3, 7.4.8, 7.5

Table 7-1. Psychological Design Process. We start designing with a detailed understanding of the target mission and its goals; then, we specify countermeasures.

Johnson Space Center between 1995 and 1997 [Holland and Curtis, 1998]. Examples of the opposite situation are more numerous. Unfortunately, psychologists usually aren't brought in until much of the mission planning is complete or until after a psychological problem arises during flight.

7.2.1 First Check

During the early conceptual stage, we consider the proposed mission concept and give and receive general information about the main parts, such as primary mission goals, duration, crew size, vehicles and habitats, overall pre-mission and in-mission timeline, and central tasks and events. We want to understand how the mission's configuration affects people: Is it workable? What are the challenges to sustaining motivation? Does it involve new exploration or routine tasks, and how is it perceived by astronauts and ground-support people? Is its duration reasonable and do-able? How frequent are the crew changes? What is the frequency, quality, reliability, and type of communications? Are the crew's size and composition workable? Are the volumes of vehicles and habitats reasonable? Does the mission allow individual space for sleeping or stowing personal gear? Do astronauts have visual privacy? What is the expected environment within and outside the spacecraft? How will people get medical care? What are the main tasks on board and on the planetary surface? How will people move about? Can astronauts abort a mission and return? What are the assigned roles and hierarchy for decision making? Where is the pre-mission training and how long will it last? What are the organizations and methods envisioned for project management, ground control and communications, training, science or technology, and other support functions? These questions represent those we should ask at this stage.

We should keep in mind that the mission concept is likely to change as discussions ensue, constraints and resources become clear, and the mission configuration matures. The psychologist has important information about human well-being and performance under various mission conditions that will greatly help early mission planning. Mission managers usually appreciate this information because they must meet behavioral, health, and performance goals to reach the mission's larger goals.

7.2.2 Determining Mission Demands

Once the mission concept is relatively mature, the target mission's unique demands drive all further activity on psychological issues. At this point, the mission planners will begin looking toward the support units, such as operational psychology, to tell them what resources or requirements they must build into the mission plan in order to accomplish the mission objectives. We must analyze the target mission and then specify the countermeasures and strategies, such as selection or training procedures, needed to offset any extreme psychological demands and optimize the crew's well-being and performance. By analyzing the mission's demands, we define the psychological targets for our tools, bind the countermeasures to the mission goals, and establish the themes that should run through our selection, training, preparation, assignment, support, monitoring, and repatriation activities. In this way, the countermeasure tools will interlock and support one another. Otherwise, countermeasures can appear to be unrelated, without clear purpose, and only incidentally related to the mission at hand.

The process of exploration naturally generates unusual psychological demands—entering extreme environments, living under

difficult circumstances, and working at the very end of the human tether. Constraints on mission success come from the environment, which is unsympathetic to our goals, and from the limitations of our technology in managing that environment. When our aspirations intersect with and exceed the limitations of our technology, then we are "pushing the envelope," and powerful psychological demands are placed on the explorers and the mission team. These demands are an inevitable aspect of exploration and are part of its reward. They constitute the personal and social challenge that no explorer would want to give up. However, as we push the envelope further and further outward, the demands can reach a level at which they begin to exact a human cost in performance or health. Just as wear and tear occur on hardware and physical systems placed into extreme service, humans experience wear and tear when placed into extreme service. Like their equipment, the inevitable abrasion that astronauts experience comes from their being asked to perform at the limits of their capabilities. Mission planners wish to sit astride the balancing point at which we maximize the mission returns while minimizing the human costs. Our role is to develop the tools which reduce or manage this abrasion, so that the margins of the envelope can be extended further and further outward.

To manage psychological effects, we need more details on key aspects of the target mission (Table 7-1 and Fig. 7-2). We'll be most concerned about conditions and events that can influence a mission's goals by strongly affecting the psychological state and functional readiness of a crewmember, the crew as a unit, or the crew-ground team. Figure 7-2 calls these conditions and events *shaping factors*, and illustrates their general effect on a mission's outcomes. To contain disabling factors and promote enabling factors, we must design countermeasures for the former and strategies for the latter.

Although some of these factors will be unique to the target mission and require experience to identify, others are common to all missions, so we must include them in the analysis step:

- *Expected Duration:* This is the maximum number of days, months, or years planned for the mission under nominal and off-nominal circumstances. Obviously, this number isn't guaranteed. In exploration, equipment failures, medical issues, or other uncontrolled events may shorten or extend a mission. Because crewmembers prepare themselves psychologically to achieve certain goals and to be away for a certain period, unexpected shortening or lengthening of the mission can affect them. Without psychic powers, we can't foresee these types of occurrences, but we should still consider them when designing countermeasures. The expected duration is more reliable in routine operations or in those using known methods, previously used hardware systems, familiar destinations and environments, and so forth. But other missions will demand that we include duration windows in our design. For example, in first-time missions, such as the first Mars or lunar station mission, inexperience may lengthen or shorten the duration. Another example is a mission with decreased home control over the logistics, such as the US-Mir missions or the International Space Station, in which political interdependencies or increased complexity may vary its duration.
- *Volumes:* The internal pressurized volume (m^3) of the mission's vehicles, stations, and habitats roughly characterizes the

Figure 7-2 Shaping Factors Enable or Disable Goal Attainment. To understand the target mission you must identify factors that promote or disrupt goals. The countermeasure tools and strategies act on these factors.

amount of habitable space available to the crew. The crew can't inhabit the entire pressurized volume because equipment, stowage lockers, instrument panels, ducting, and other gear take up a great deal of it. Still, if we are to compare roughly the target mission's volume against that of a previous mission with known psychological outcomes, the pressurized volume is currently the only metric that is available for all missions.

- Volume Moderators:** Although we must compare pressurized volumes, we can refine our estimates by accounting for the number of people on the crew and the amount of time they'll be operating in that volume. Dividing the habitable volume by the crew size gives us an idea of the social density, or the volume that is roughly available for each crewmember. Some general expectations regarding psychological adaptation and quality of worklife can emerge from finding previous missions with the same size crew as the target and then looking at volume differences. Similarly, if we understand previous missions of similar volume, we can estimate some effects from crew size. Some operations personnel further divide this number by the expected mission duration to get a rough index of confinement [Holland and Longoria, 1991]. But we must be careful not to base behavioral expectations on any single variable such as volume, because:
 - many variables influence individual and crew functioning outcomes.
 - few well-researched space and analogous missions are available.
 - no one has systematically determined the behavioral

significance of indices that combine volume, crew numbers, and mission duration.

- Crew Characteristics:** The number of crewmembers usually depends on the number of people, skills, and roles needed to accomplish the mission's tasks. As outlined in Chaps. 6, 17, and 24, factors such as launch weight and life support also drive this number. We also need to know the probable genders, cultures of origin, assigned roles, technical skills, command structure, and relative experience because they bear on the crew's behavior. Characteristics of the individuals' personalities, attitudes, work habits, leadership styles, and language abilities are also very important, but this information sometimes isn't available to us until after the requirements are developed. Once the individual crewmembers are named to the mission, we can tailor the core countermeasures and strategies.
- Physical Environments:** What are the physical environments in which the astronauts will work or live? Here, we must gather as much detail as possible about these environments. For example, we must consider the nominal thermal, lighting, noise, radiation, and visual environments. We determine how much freedom of movement the astronauts will have, what kind of atmosphere they'll live in, and the amount of time they'll spend outside a vehicle or station. We also consider the crew's organization, allocations of individual spaces for sleeping and for personal items, visual and auditory privacy, ability to alter the physical environment, types and levels of risk to health or life, and other aspects of life in space.

- Work/Rest Characteristics:** Variations in work tasks, workload, rest, and leisure time affect the crewmembers' mood, attitudes, energy levels, expectations of the future, tension with others, and so forth. For example, periods of sustained low or high workload were stressful to crewmembers on the Mir station, although the two had different effects. Similarly, the perceived relevance of the work tasks to the mission goals strongly influences individual motivation, crew morale, and crew-ground relationships. Other important factors include the amount of time allocated for sleep, relaxation, and work; the frequency and extent of sleep shifting expected because of critical mission events, such as EVA; operations over single or dual shifts; using a unified daily schedule for the crew; and similar information. We should consider the mission planners' experience in this area, as well. To date, no country has learned how to successfully implement realistic work-rest schedules for long-duration flights. For example, in both the Skylab and Mir programs, the amounts of time that were allocated to the crews for various tasks were typically far too short for what was required to locate the necessary materials, set up the tasks, perform them, and stow the materials. It is frustrating for goal-oriented crewmembers to be faced repeatedly with impossible timelining and not be able to complete expected tasks. It is also frustrating for ground-based scientists and technical personnel not to receive as much data as planned. For a number of reasons, this is more of a problem on long-duration missions than it is on short ones. The short-duration "sprints" are more amenable to tight timeliness the long-duration "marathons" require a slower work pace and considerably more flexibility. Scheduling methods which give more control to crews on long-duration flights are likely to be more successful. The preflight timeline determines how much remote and intensive training can be proposed. The postflight timeline projects the estimated physical rehabilitation, rest, and emotional recovery crewmembers need before they should return to office duty or flight status.
- Autonomy:** We must review the expected role of ground control, along with the mission philosophy, to understand how much autonomy the crew will have during the mission. We need to know who keeps the inflight schedule, who can change it, and how much the crew depends on ground control for technical direction, resupply, task information, contingency decisions, and so forth. In general, where does the locus of command and control lie during the mission, and under what circumstances does that change? Communication and provisioning capabilities strongly influence autonomy. For example, missions with a significant communications time lag (such as those to Mars) mandate much more autonomy than lunar missions.
- Communications:** Closely related to autonomy is connectedness - how readily can the crewmembers contact ground control or family members when desired and what are the expected type, quality, and frequency of these communications? What constrains communication? Married crewmembers seem to want more two-way video communication and more frequent communication in general, especially when they have young children at home. What constrains uplinked news, electronic mail, packages, video, and remote participation in activities

on Earth? Communications are often routed through various ground stations, satellites, and on-board computers, so maintaining privacy is difficult. We want personal communications to be as confidential and direct as possible—encrypted and passed through as few hands as possible. If some channel of communication fails, what backup channels might serve? We must understand communications to design support strategies.

- Contingencies and High-Demand Scenarios:** We should gather as much detail as possible about the crew's activities before, during, and after the mission, so we can identify times of higher demand. We must identify any events or situations that might affect one or more of the crewmembers. Examples might be taking a critical systems test in a non-native language, inability to contact a family member from an international training site, launching a fatigued crewmember, or contingency situations, such as collisions of vehicles, extreme thermal conditions, or death of a family member on Earth. Others would be a delayed return to Earth or various types of conflict within the crew, such as role confusion, personality, work attitudes, or cultural misunderstandings, conflicting instructions from the ground, or post-mission depression. Some of these scenarios will be unique to the target mission, but we can predict others from history. The scenario approach to characterizing psychological demands is an important supplement to information about the conditions, because it can point out demands for specific skills and abilities that we wouldn't otherwise foresee.

Over time, the mission environment and events can take their toll on the crew and ground personnel. Latent stressors accumulate to affect their psychological health, well-being, and performance. Such stressors include extended confinement, separation from traditional social support, sensory tedium, high social density, and sleep shifting and sleep loss. Communication difficulties, low tolerance for errors, and the absence of familiar comforts also contribute. But these disabling shaping factors can be minimized through countermeasures and strategies which protect and expand the enabling factors.

With the key mission factors and scenario information in hand, we can conduct a *mission demand analysis*. We can determine the psychological demands of a mission in several ways [Holland and Vander Ark, 1993]. Figure 7-3 presents one method which identifies the conditions and constraints within which the crewmembers must work and live, the critical situations to which they must respond effectively, the proficiencies that the crewmembers must have, and the crew and organizational capabilities that must be in

place.

Figure 7-3. One process for Analyzing Mission Demands.

Analyzing a mission's demands requires a completed Goal Attainment Model. We begin with the mission goals and establish a cascading set of contributory goals for psychology and performance. (See Fig. 7-1.) The number and arrangement of goals, levels, and linkages in our model aren't as important as making a case for whatever goal model we construct. As research and experience with space missions increase, the goal model should evolve to reflect new learning about content and linkages. Before starting our analysis, we'll need to chart what's known or expected regarding key mission characteristics, such as the nine common shaping factors mentioned earlier. We'll also need the mission's expected technical timeline, including all known significant events and activities:

1. Pre-mission events, such as systems training, news conferences, or trips abroad
2. In-mission events, such as extravehicular activities, critical tasks, trajectory changes, resupply, and science tasks
3. Post-mission events, such as data collection, debriefings, return home, and scheduled ceremonies

For now, we position these events and activities on the timeline without psychological countermeasures.

With the goal model, key mission information, and timeline in hand, we can start identifying the nature and severity of threats to the goals. For best results, we recruit participation from subject-matter experts:

1. Veteran astronauts who have been on very similar missions
2. Space psychologists, behavioral specialists, or flight surgeons who have worked closely with astronauts on similar missions
3. Astronauts who haven't flown, such as backups who went through preflight training for a similar mission
4. Key ground personnel, such as console leads, who worked closely with an astronaut during a similar mission

If the target mission differs radically from any previous mission, we can usually locate participants who have first-hand experience with part of the target mission, such as preflight training, or with one or two of the same shaping factors, such as the same volume, crew size, or duration.

An alternating discussion and voting process ensues in which our group starts at the top of the model and assigns weights to each of the goal boxes according to its criticality or contribution to the goal boxes in the next highest tier of goals. For example, we would discuss goals for "Individual State and Functional Readiness" and their relation to mission accomplishment, then assign a weight to this goal box. We move through each goal box on this level and then address the next lower level, evaluating goals for "Individual Psychological Health and Well-being" against each of the three boxes above them. Then, we combine these three values to yield a single weight for "Individual Psychological Health and Well-being." Ultimately, we assign each goal box a single weight that estimates its criticality to mission success. Several commercial software packages are very good for group decision making, as well as for computing weights and organizing results from this process.

After we've delineated and weighted the goals, we address the enablers that can help us achieve them. We consider each goal box separately and brainstorm events, conditions, abilities, tools, and factors that could enable each goal. We include organizational poli-

cies, strategies for preparing families and ground personnel, generic selection and training programs, and so forth. We focus on attaining the goal, not on offsetting any disabling factor. Once we have a draft list of enablers, we map them onto the timeline so we can relate them to events or phases. Often, we'll discover more enablers, which we can associate with a goal and add to the final list. Now, we discuss each enabler and assign it a weight based on three values: (1) its potency, or ability to help attain the goal, (2) implementation practicality, and (3) the weight of the goal with which it is associated.

Next, we identify and characterize factors that could defeat the goals. Again, with one eye on the key mission characteristics and timeline, we consider each goal box separately and brainstorm events, conditions, and factors that (singly or combined) would threaten each goal. When conditions or events must occur simultaneously or jointly with one another to create a threat, we carry this cluster as a single threat. We can derive important threat information from the group's experience, previous missions, and research findings. Also, we assume some medical incidents will occur, as will failures in various hardware, software, and critical paths of communication and supply.

Once we've completed our draft list of threats, we map them onto the timeline. As with enablers, this mapping will give our group a chance to identify time-related or event-related threats we had overlooked. For example, chronic negative conditions, such as extended confinement and separation, can change moods, motivation, or social environments over time. Similarly, an event such as a death among the crew or among family members is often followed by a period of altered workload. We associate these conditions with a goal and add them to our list of threats. After we generate the threat list, we discuss each threat and assign it a weight based on three values: (1) its potency, or ability to thwart achievement of the goal, (2) its probability of occurrence, and (3) the criticality, or weight, of the goal box. We discard threats with very low weights, unless they have a high potency. Then, we remap the remaining threats onto the event timeline.

7.2.3 Resource Knowledge Base

Before we finish analyzing demands and determine countermeasures, we should access all reliable knowledge on these issues. We must carefully gather and sift through this knowledge because information and experience vary greatly in quality and relevance. Only a few crewed missions occur each year, so only a small number of astronauts and crews exist. That means high-quality behavioral science and direct operational knowledge is very limited, particularly for lengthy spaceflights. No doubt this deficiency will improve with time, but we'll always need to separate carefully the "wheat from the chaff."

Scientific and experience-based information are both important for good mission design. Scientific journal articles contribute to how we'll characterize the psychological environments for various mission configurations and to the basic processes that occur as crewmembers adapt to these environments and pursue their mission goals. The rigorous scientific process generates information which is substantially reliable and usually provides important insights about, specific questions. This approach is also invaluable to design areas that receive conflicting anecdotal information, such as from individual crew reports.

Experienced practitioners, who have developed and applied real-time tools, techniques, and countermeasures to space missions,

contribute their experience and lessons learned under actual mission conditions. This can save us a lot of time and the mission manager headaches by avoiding past mistakes. But practical experience is anecdotal in nature, so we must use it with caution. Technical documents from domestic and international space agencies are also important sources of information, although they are often hard to find. If we can't get information from space operations, documents from nonspace organizations—such as polar, expedition, or defense organizations—that conduct psychologically similar missions can be helpful.

Of course, we should also consult astronauts who are veterans of similar missions to get another perspective on psychological issues from people who were actually "there." In considering these views, we must keep in mind that astronauts vary widely in their personalities and adaptive abilities. We should not use only one or two astronauts' opinions; even members of the same crew show marked differences in experiences and reactions. Instead, we gather information from various sources and reconcile differences in light of their context.

When sifting through all these sources, it's tempting to make broad assumptions which can mislead our design process. For example, assuming "the type of psychological problems that often occur in polar bases will occur on space stations" can lead us to errors in training. The psychological environments of polar bases and space stations differ in key respects, such as the team size, length of pre-mission training together as a unit, and schedule control, among others. The same can be said of previous, analogous space missions. We should beware of superficial similarities and carefully examine the similarities and differences between the target mission and its analogues before making assumptions that drive our design decisions [Holland and Wood, 1993].

After searching the knowledge base, we can make our initial analysis of mission demands more accurate and complete. Similarly, we start to line up countermeasures against factors that threaten the mission goals.

7.2.4 Countermeasure Tools and Enabling Strategies

The mission's demands determine our choice and design of countermeasures and enabling strategies, such as:

- Screening and selecting astronauts, including criteria, tests, interviews, scoring and reporting procedures, data access, and stages of selection
- Training and preparing individuals, leaders, and entire crews, including objectives, proficiencies, content, procedures, hours, simulations, debriefings, and family participation
- Methods of psychological support before, during, and after the flight, including types and amount of communication, resupply packages, on-board materials for leisure and recreation, logistical procedures and approvals, dependencies on other organizations, required on-board hardware and software, and family resources
- Ability to monitor crews during the mission. We should consider how much, what type, assessment reliability, required on-board hardware and software, security and confidentiality issues, data handling, and so on.
- Ability to intervene during the mission, including ground rules, quality of pre-mission relationships, communications security and logistics, crew training and self-care skills, and on-board medications
- Repatriation after the mission, including debriefings, recency

from landing, frequency, length, attendance, confidentiality, family debriefings, and leave time

Countermeasures are specific activities and processes designed to thwart identified threats to mission goals. They offset the mission environment's potentially debilitating and destabilizing effects and support positive adaptation and effective performance. Some countermeasures are directed to individuals, some to the entire crew, and others to the ground-support team or its interface with the crew.

Enabling strategies are procedures and organizational policies that ensure preconditions needed for effective work or which optimize normal behavior and performance. An example of providing preconditions needed for work might be a written policy that defines the medical and travel benefits for crewmembers or ground personnel who deploy abroad. Another example might be acquiring multi-entry visas for crewmembers and ground personnel who must repeatedly travel abroad. Optimizing strategies would include faster sleep-shifting of crewmembers, improving air-ground video communications, and improving on-board training methods.

All strategies and countermeasures aren't equally important, of course. The mission goals and psychological goals vary in criticality, and the threats to those goals vary in potency. These variations point us to the areas that are more important for mission success.

At this point, we characterize what individual crewmembers, the crew as a unit, and the ground organization must do to master each weighted threat. We consider their adaptation, individual and team proficiencies or skills, and conditions and behaviors. Then, we weight these behaviors, conditions, and proficiencies within each threat according to their estimated potency to offset it. As with mission analysis, we can use a working group to help us brainstorm. This step translates each goal threat into a weighted demand on human systems—expressed in terms of needed behaviors, behavioral capabilities, or conditions. Now, we separate conditions that management or some other part of the organization clearly controls from behaviors and proficiencies. For example, a policy on maintaining unmarried crewmembers' homes during lengthy missions is under management control. However, the ability to adapt to extended confinement is a proficiency or behavior. Later, we'll combine these organizational policy issues with similar ones from our list of enablers and move them forward to the requirements stage. We follow a similar process for weighted enabling strategies, listing actions needed to implement or protect these enablers during the mission.

Now, we can use the weighted behaviors and proficiencies to help us select countermeasure tools. These tools will help ensure that the mission team possesses the critical proficiencies and will make key behaviors when needed. Be very careful though, when choosing among potential techniques and procedures. We must keep in mind these guidelines:

- *A gram of prevention is worth a kilogram of cure.* Our best investment is in tools that prevent difficulties or give crews the ability to detect and master whatever threats may come their way [Holland and Marsh, 1993]. Once the vehicle is away, ground specialists can't intervene as effectively, and the great majority of inflight behavior or performance problems are preventable before the flight.
- *Use the right tool for the right job.* Just because a psychological tool exists doesn't mean it is the right tool. Clearly a screwdriver, not a hammer, is appropriate for tuning a car.

Also, screwdrivers vary greatly in type, size, coverings, endings, insulation, power, and so on. Working on a short-wave radio requires a very small screwdriver with a special tip, similar to those jewelers use. Repairing a skull in surgery requires another specialized version. In the same way, psychological tasks demand varying tools. For example, we may decide interactive software can best introduce crewmembers to certain concepts and their supporting data. However, mastering a skill related to that concept may require a simulation. And we may need to make changes and add conditions to make the tool hit dead-on. We must carefully target a psychological tool to the threat it addresses.

- *No tool is an island.* Each psychological activity is part of an integrated design whether it is part of preflight-including selection, advising organizational policy, and preparing the crew or whether it extends through the flight to the crew and the larger mission team. We're trying to create a system of related and mutually reinforcing activities that lead to mission success. Although we must consider some tools individually, they must dovetail and work together to produce a certain result. A good, integrated design should contain common, linked content themes that can be traced from mission demands, through the selection criteria and training content, and on through the monitoring and support approaches.
- *Good pedigree is essential.* We choose tools that have a track record or that show great care in their construction. How well a tool addresses its target threat is its *validity*. Types of validity include predictive, concurrent, content, and construct [Gatewood and Field, 1990; Muchinsky, 1993]. These specific descriptors tell us something about the tool's effectiveness. Some tools can demonstrate statistical evidence, some can demonstrate nonstatistical evidence that links them to a threat, and others can demonstrate only "face validity" or apparent linkage. Similarly, various types of *reliability* associated with tools tell us about the constancy of their effectiveness. Some tools, as I'm using the term here, can't be statistically validated because of their structure or because they are applied to very few individuals. In many situations, we won't have time or resources to complete validation studies before using a tool. But we can carefully review its origin, development, other applications, and potential for effectiveness to establish some confidence in its pedigree. Later, we can improve and modify the tool through validity studies. Because a full discussion of validity and reliability is beyond the scope of this chapter, see Cascio [1998], Guion [1991], and Landy and Kohler [1994] for more details.
- *Users must accept a tool for it to be effective.* Regardless of a procedure's validity, it will fail if astronauts don't see it as useful as something that would tangibly improve conditions on board or the chances of job or mission success. The tool also must fit the realities and constraints of the training and flight environments. Thus, we should ask knowledgeable astronauts what they think of a tool early in the design process, so we can change it if necessary. If veteran astronauts are part of our working group, as described earlier, they're in a good position to guide us on acceptability.
- *Don't put all the eggs in one basket.* When a goal is critical, we use multiple, parallel paths to protect it. Also, we use redundant tools when attacking high-weight threats. During space operations, hardware and software fail, the schedule is

reworked to handle unforeseen tasks, and so forth. Any of these events can sink our countermeasures or enabling strategies. For example, if we rely heavily on communications between crewmembers and their families, we should expect one or more communication paths to be out of order, sometimes simultaneously, and plan for a backup method. Mir saw periodic power shortages, overheated transmitting equipment, misalignment with the communications satellite, and other conditions that prevented use of the main communication paths. Consequently, Mir used amateur radio for family connections and news uplinks—a reliable "back door" when primary methods failed. Similarly, if it's important that a crewmember access a certain training diskette in flight, assume the computer needed to run that diskette won't work properly at some point. Before flight all alternate method should be part of the design.

- *We will need to tailor most tools.* Astronauts vary widely in their personalities, preferences, work styles, and values. Crews are also unique in the way they work, their relationships, their social climate, and so forth. To make tools and strategies more effective, we modify them slightly to account for these variations. Not all tools can be individually tailored, however. For example, criteria and procedures for selecting applicants must be held constant across applicants.
- *Create no dependencies.* Future space missions will include exploration missions to other planets in which there will be a significant communications time lag between Earth and the vehicle. Similarly, some missions will establish a station or small colony on the lunar surface or on another planet. These missions will require much more autonomy for crewmembers than current ones. As crews take on more operational responsibility and authority, ground-support organizations must profoundly shift their thinking about their own roles, processes, and structures. At the same time, psychological tools will be required which promote self-sufficiency rather than dependency on Earth-based resources. Even in today's era of space stations in low-Earth orbit, significant problems remain in balancing the need for a crew's control over its own schedule, pace, and work methods with the need for Earth-based systems expertise, information resources, monitoring, and ascent or entry tasks. Technological limits in today's space hardware, propulsion, and information systems mandate a tight interdependency between crew and Earth. Yet, this interdependency remains a source of frustration and excess work for crews and ground personnel. Space organizations should begin now to devise ways that will safely and productively increase independence. Toward this end, we should build tools that don't promote crew dependency on Earth-based psychologists. For example, crews need more skills and on-board tools to monitor and adjust their own health and performance, thus replacing many monitoring activities and conversations with the ground.
- *Critical resources are limited.* Psychological operations must compete with many other demands on crew training time, funding, manpower, and other scarce resources. We must design, choose or modify tools so they're as effective as possible under tight resource constraints. These constraints call for intelligent compromises during tool selection and design. Suppose we need a powerful light source on board to shift crewmembers' sleep and circadian cycles, but have very lim-

ited electrical power on board. A solution may be to alter the degree of shift or use exercise in place of light. Or suppose psychological training is estimated to take 96 hours but only 48 are available. In this case, we could fight for more time, redesign the proposed training, or create new ways to move pieces of the training forward into early basic training or back into the mission itself. We could also adapt the content to other modes, such as computer-based training or video, identify pieces which could piggyback onto technical training, and so forth. On the positive side, constraints force us to invent new ways of delivering training and novel solutions to technical problems.

- *Recognize cultural influences in concepts and tools.* Multinational space projects bring together countries with very different cultures and psychological concepts. The International Space Station represents an extraordinary number and breadth of cultures. Concepts that describe important social and psychological qualities in Brazil may not exist in Canada. Certain emotions and thoughts viewed as sub-clinical precursors to psychiatric disorders in one country may be relatively unimportant in another. Japanese astronauts may view as part of good leadership behaviors that Russian cosmonauts see as ineffective or even dangerous. For multinational missions, we must resolve key cultural differences in order to adopt common tools, attach the same meaning to information and behaviors, and extrapolate effective joint actions from a rapid stream of mission events. At a minimum, we must check for cultural assumptions in traditional and proposed tools and work with international counterparts toward a common definition of key concepts [Holland and Looper, 1990; Holland, 1994, 1997].
- *Clarify upfront the data handling and confidentiality for each tool.* Psychologists commonly work with information that may be sensitive to an applicant, crewmember, family member, or mission manager. This sensitivity is part of designing and using psychological tools. The trust that underpins our effectiveness in this area is a hard-won prize, so we must guard it by considering the data handling and confidentiality issues associated with each tool. From the beginning, we build into each tool how we'll manage sensitive information—store it, transmit it to others, use it in critical career or mission determinations, and so forth. People who contribute or use sensitive information must clearly understand the procedures and ground rules. Investing effort in this area pays significant rewards.

Now that we understand the goals, threats, enablers, and tool guidelines, let's look at some specific countermeasures and strategies. In the following sections, we'll examine representative tools for the preflight, inflight, and postflight periods (summarized in Tables 7-2, 7-3, and 7-4).

Psychological Tools for Preflight

Policy consultation: Frequently, conditions and events that create the most psychological difficulties for a crew during a mission don't come from the mission environment; they arise unintentionally from procedures used by the ground based mission team, or from outmoded organizational policies, which work against goal accomplishment. Snafus, obstructions, inattention, and dropped opportunities by supporting organizations can bedevil and distract crewmembers from their training and flight responsibilities.

Repeated occurrences can undermine confidence in the work-support structure and in management's ability or commitment to support the crewmembers. We may be tempted to leave organizational policies and procedures to others, but these critical and often overlooked issues directly affect the crew's health, performance, and well-being. We shouldn't make policy, but we should identify the needed areas, help the organization discuss these points, offer our input, and provide technical information that policy makers can use in their decisions.

The previous design steps yielded some enabling strategies and threat countermeasures that organizational policies and procedures can address. At this point we should collect and begin comparing them with current procedures. We gather information about practices and lessons learned from similar operations, such as underwater or polar missions. Then, we work with others who "own" these areas in our organization and with those who could help champion any needed changes. Past topics for policy consultation include length of time training abroad, family travel and visits, communications during deployment, caring for unmarried crewmembers' houses while they're on a mission, establishing a family-support office, resupply frequency and amount, shifts for ground personnel, amount of postflight leave, crew handover time, sleep shifting, and many more.

Habitability consultation: Specialists in human factors and environmental design have the expertise to influence psychological health and performance through the design of the physical environment. Chapters 6 and 18 detail this topic. Mission managers often ask psychologists to weigh in on habitability, so we should coordinate early with those in charge of vehicle or habitat architecture. We must make sure the psychological tools and enabling strategies support requirements for habitability, crew accommodations, and human-factors design. We investigate analogous operations for their experience and practices. Engineering designs and reviews too often exclude psychological considerations until it's too late or too expensive to incorporate them. Examples of past habitability topics include the need for windows in a station, noise levels, issues about domestic and foreign foods, on-board freezers, privacy in sleeping compartments, and so forth.

Screening and selection: Just as with sport or military teams, the screening and selection for spaceflights is ongoing, with activities that wax and wane over time. A flurry of this activity occurs at the organization's "front door," where applicants wishing to become astronauts apply for entry. It creates a pool of generally qualified people from which the organization can select flight crews. But psychological selection activity should also extend through basic training and to the assignment of individuals to particular missions. Methods differ at these various points, but I'll address only the "front-door" activities to stay within the scope of this chapter.

Initial methods reduce a large applicant pool to a smaller group in whom we are somewhat confident about future performance. Beginning with the target missions' demands, we choose the tools that will produce the highest level of confidence. Time usually constrains front-door methods, but if the organization has the foresight and will to continue a process throughout training and flight assignment, they will fulfill their purpose to provide the initial screen. When we balance limited time against the need for thoroughness, we should consider the stakes of the target mission, the complexity of the demands we're assessing, the adequacy of downstream training and assessment, and the financial and manpower

Class	Tool	Note
Policy consultation	Advocate best practices; use information from other settings	Postflight leave, ceiling on training time abroad, travel policies, etc.
Habitability consultation	Advocate best practices; use information from other settings	Noise, privacy, food, stowage, etc.
Screening and selection	Select out: testing, structured interview, feedback Select in: testing, structured interview, structured reference interview, experiential exercises, computer-based exercises, feedback	Medical criteria Nonmedical criteria: fit and suitability of a person for a job Overlap with training and preparation
Training and preparation	Consider previous lessons learned, crew-ground integration and coordination, personal strategies for preparing and adapting, confined team operations, simulations and experimental scenarios, cross-cultural and language training, leadership, coordination with the ground team, family meetings, advanced psychological skills, electronic methods	Individual, family, crew, ground Integration of prime and backups for crew change outs Key interfaces among ground team Increase the crew's autonomy
Crew assembly Deployment support	Psychological testing, experiential exercises, sociometrics Extended communications by audio and video, participation in regular meetings, rest and recreation facilities, family support	Overlap with training and preparation Mitigate "we-they" thinking

Table 7-2. Sample Preflight Countermeasures. Preflight countermeasures are the most important and cost-effective group of tools because they can prevent problems.

investment required. The front-door methods are valuable because they quickly and reasonably estimate an individual's abilities and vulnerabilities. This estimate is an initial snapshot that must be revised and filled in after the person has entered the organization and been seen in various training and operational situations.

Though actual spaceflight is a relatively small (but critical) part of an astronaut's job, we should consider the entire job in our front-door methods, including ground-based tasks, training tasks and environments, public relations, community outreach (if any), and so forth. Also, front-door procedures usually select people for a number of different missions, so we need to address these wide demands. For example, NASA's front-door procedures consider short and long missions. Whatever the target mission, however, we must ensure our procedures follow the guidelines for effective tools, especially those regarding pedigree.

In general, any selection system must answer at least two questions: (1) Is there any evidence of clinical traits or psychiatric dysfunction that would impair the candidate's health or performance on the job and mission? In other words, is the candidate fit under the medical criteria? (2) To what extent does the applicant have the psychological capabilities or behavioral skills to perform well on the job and mission? In other words, does the candidate satisfy the nonmedical criteria? The first question pertains to applicants' general psychiatric experiences and resources and to the probability of their developing clinical symptoms before, during, or after a flight. Also we must consider whether applicants are likely to develop *sub-clinical* features or maladaptive behaviors that might be problematic. The screening procedures that address these clinical questions compose a "select-out" process. The second question addresses normal personality characteristics, past psychological experience, and the applicants' ability to adapt to, and work under, the mission's psychological demands [Holland, et al., 1997]. It's a question of suitability, or job-person fit, and of picking the best people for the mission. We also consider whether applicants can bolster any liabilities through psychological training. These selection procedures are part of the "select-in" process. Select-out and select-in processes help us determine whether applicants probably can adapt to environmental challenges, such as extended confinement, sleep deprivation, or crowding. They also indicate whether candidates are likely to manage social demands, such as team organization, multicultural crews, extended group living, or separation from family and home.

Initial psychological methods can be of any type, but we typically blend various traditional or custom personality tests, biographical and experience assessments, clinical and non-clinical structured interviews, and reactions to simulated mission conditions or situations. We design this blend to match the specific capabilities we're seeking, include the most powerful tools available, and complete the assessment as quickly as possible. Because every tool has its own strengths and shortcomings, we incorporate tools with mutually supporting strengths and offsetting liabilities.

For example, we balance "objective" methods, such as paper and pencil tests, computer or CD software, videos, and electronic or physiochemical equipment, against more "subjective" methods, such as structured interviews, veteran ratings, and expert ratings of performance in special situations or environmental conditions. Objective methods have been highly quantified and easily lend themselves to review for bias and validity. Subjective methods often do a much better job capturing capabilities or qualities that are difficult to define or quantify. For subjective information, we focus on veteran astronauts and behavioral experts who especially understand the target mission's demands and who have trained in the assessment procedure. In a sense, objective information provides the "bones" of an individual's abilities and liabilities; the interviews add substance, explanation, and a human face; and the experiential tasks tell us about the applicant's behavior under specific situations or environments. We then validate all methods against criteria of importance to the mission or organization.

After integrating all information, we make our recommendations to decision makers. We can do so in several ways, but we should at least ensure that several knowledgeable people are involved to further check natural human biases. At NASA, two people sit in on every structured interview, and six to ten experts review and discuss the findings on each applicant. The clinical, select-out recommendation is "go/no go," which then moves to a medical selection board. The board integrates this recommendation with those from all other clinical disciplines to yield a single, medical, "go/no go" decision for each candidate. The nonmedical, suitability recommendation consists of ratings for short and long missions. They go directly to the astronaut selection board. Because most applicants have never been through such an extensive process for psychological selection, we should allow time for brief talks with each applicant about their results. We can guide rejected candidates who may reapply, establish a rapport with people who were accepted, explain the process and tools, and further inform candidates about psychological demands on individuals and families.

We continue selection procedures beyond the front door into basic training and preparation. When applicants apply for a job particularly a job they want very much they naturally tend to "put their best foot forward" at the front door. It's important to see them in training and work settings, so we can accurately understand their psychological capabilities and behavioral skills. We integrate some screening and selection activity with the candidates' early psycho-

logical training. This is a way for the organization to "thump the melon" rather than buying it on appearance alone.

The benefits of effective screening and selection are broad, positively affecting the individual, other crewmembers, key ground personnel, and the entire organization. Good selection exerts a powerful effect on attainment of mission goals, and it endures over the course of preflight training, mission execution, and postflight repatriation.

Training and preparation: The power of psychological training and preparation begins at the natural limit to selection's effectiveness. Training tools can offset shortcomings in selection, clarify important mission values, and instill advanced psychological skills that most applicants won't have at the front door [Holland, 1991]. As shown earlier (in Fig. 7-2), demands and abilities exist for individual astronauts and the crew, as well as between the crew and key operators on the ground. The training design should meet these demands by increasing the individuals' capabilities, skills, and strategies.

Crew training and preparation consist of three main phases: basic, advanced, and mission-specific. All new astronauts take basic astronaut training to learn about spaceflight hardware, land and water survival, vehicle systems, mission program objectives, life science research, medical issues, basic psychological concepts, and other topics. Examples of psychological concepts are leadership styles, cross-cultural information regarding international partners, team operations in a confined environment, and so forth. Early personal and family preparation begins in basic training as well; candidates receive personal information and guidance on ways to mobilize strengths and manage characteristics that would be liabilities on a mission. They also form important values and attitudes that underpin psychological skills and capabilities.

With the conclusion of the Shuttle-Mir Program, NASA now has two distinct types of missions: relatively short Shuttle missions and relatively lengthy missions for the International Space Station. Because the psychological demands are much greater for the latter, the tools for psychological training are different for the two types of target missions. Consequently, in a multi-mission environment, we should use basic training to address the core capabilities and values all missions share such as group living and leadership in confined settings, cross-cultural work styles, and effective teams.

We need to take the same care in choosing training and preparation tools that we take in choosing selection tools. Many training tools have face validity but little empirical evidence to attest to their effectiveness, so we must attend to issues of pedigree, validity, and reliability. We try to validate all training countermeasures. Because we can measure training effectiveness at several points in the process, we also evaluate new tools against those criteria. The same issues of "objective" and "subjective" methods I discussed earlier under selection also will be present in training. This is also true for integrated, multinational training and evaluation, for which a behaviorally based indicator may help bridge the cultural gaps.

Advanced training addresses more sophisticated abilities and includes skills linked to the demands of a specific mission or mission type. Examples of these advanced topics would be very accurate simulations of high-demand scenarios, such as responses to decompression or smoke in the cabin. Another possibility is practice with advanced leadership strategies, such as multinational problem-solving and negotiating solutions. A third is confined team operations in an analogous environment, such as work-schedule scenarios in an underwater habitat. After revisiting the mission

demands, situations, and conditions, we begin with what capabilities are needed by launch day and work backward through the instruction and experience needed to get there. To do so, we answer a number of questions: How do we define the capabilities in terms of the conditions and situations under which they must be used? What materials, settings, venues, and other resources are needed? What evidence or indicators of proficiency will we use to evaluate the students and training tools? What would be an effective delivery sequence? How should extreme locations or conditions be used, if at all? The resulting tools will most likely blend briefings, computer or other electronic interaction, and direct experience. We can use the data from earlier psychological testing to help counter shortcomings and use strengths as cornerstones of an individualized plan for personal development.

In the advanced phase we want individual astronauts to become fully competent in using skills and strategies for managing themselves, their crews, and their relations with people on the ground. We may use advanced techniques to build simulations, creating very powerful experiences that shape emotional and behavioral responses under extreme duress. Other techniques can enable people to maintain their motivation for long periods under suboptimal conditions. But we should keep the mission's demands foremost in our minds, so risks and investment in training match the need. If we use extreme analogous environments or conditions, we must make sure they're necessary. If we choose training venues that have face validity but poor relevance to goals, we risk having the training miss its mark, being perceived by the astronauts as irrelevant, or even inflicting unnecessary injury or stress.

The mission-specific training phase occurs after astronauts have been assigned to a particular crew and flight. Assigned astronauts train together toward a set of technical tasks for the assigned mission. Because previous training has already given them the skills to cope with the mission's foreseen demands, we use what little time is available to focus these skills on the upcoming flight. Key psychological activities include helping crewmembers form action plans for adverse events; building the crew into a cohesive team; integrating any foreign astronauts; informing and preparing family members for the mission's demands on them, and making crewmembers familiar with the commander's style.

Throughout the missions that follow basic training, an astronaut's available time for psychological training and preparation is alternately compressed (at assignment to a mission) and expanded (at the completion of a mission). Before assignment to a new mission, astronauts can develop new skills or brush up on old ones because of less pressure on training time. This time can be used to practice skills in competencies such as cross-cultural leadership, for particular classes of missions, such as lengthy station tours. Once they're assigned to a mission, activities multiply, so psychological training and preparation must use less time and must focus the crew on the upcoming mission. Formal training, except self-directed training, stops several months before launch. Individual and family preparation increases during the assigned phase and continues until launch. Once the mission is complete, crewmembers return to unassigned status, and the cycle begins anew.

Education and training for the crew's families are important parts of design. Family members can support the mission better when they're informed about its stages, the procedures for contingencies, inflight conditions, the procedures for inflight communications, postflight issues, and so forth. In the past, training in cross-cultural concepts and skills has enabled the families of multina-

tional crews to integrate more quickly and thereby accelerate and extend the crew's integration. We must also ensure that the ground teams train in crew-ground communication, lessons learned from previous missions, pacing and self-care (e.g., sleep and rest, family issues), and crew stressors. Another technique useful in past missions has been briefings to mission managers about psychological lessons learned.

Crew assembly: The process by which mission managers assign individual astronauts to a mission crew is one of the least researched and understood areas of design. Technical expertise primarily has driven crew assembly for short missions, and compatibility has played only a minor role. Mission managers have relied on their knowledge of the potential flyers to select the mission commander first and then confer with the commander in selecting the rest of the crew. As missions lengthen and as the behavioral risks increase, however, psychological factors naturally must play a larger and more systematic role in determining the crew's composition. Certainly people must have the social skills to negotiate the increased stressors associated with living nose-to-nose in crowded and socially tedious circumstances. Assuming selection and training countermeasures have ensured the candidates have these abilities, how do we choose the most compatible crew? An individual can be technically, psychologically, and socially competent for the mission but have a style of working or behaving that doesn't mesh well with at least one other candidate. Social preferences among individuals are based on many historical reasons, past incidents, opinions about best ways of working, attitudes and zones of comfort, social habits, confidence in skills, and so forth. These preferences are sometimes clear and sometimes extremely subtle.

To address these issues, we should marshal the very best source of information on compatibility: the potential crewmembers themselves. Individuals know best whom they prefer to work with and whom they do not, even if they have difficulty articulating the reasons. If the training design has been effective, the potential flyers will have had numerous opportunities to evaluate one another. We can weave assembly assessment into advanced psychological training so we and the potential crewmembers have more than one chance to rate compatibility. Because fewer people will be in advanced training, we can rotate them through small-team situations so that membership and leadership opportunities change. More group situations will give us a broader cross-section of responses and actions that can show how compatible people are.

A small example of this process is the 91-day mission of the Lunar-Mars Life Support Test Project [Holland and Curtis, 1998]. Selection and training narrowed the potential candidates to a group of eight, from which four would be chosen for the prime crew inside the chamber. After team training, each of the eight candidates rated one another on compatibility and crewmate preference for this long mission. These confidential opinions, combined with those of the behavioral experts and mission managers, were very valuable in assembling a highly compatible prime crew. Of course, technical skills constrained the range of these compatibility determinations, but the procedure gave crewmembers some ownership and influence in a process that was important to their future.

Deployment support: Most government and private organizations understand the value of maintaining positive performance and health in key people abroad. Without such an investment, the home organization and crews will have to deal with lowered performance because crewmembers have to spend undue time solving living difficulties. Results include fatigue and distraction, less attention to training, adjustment difficulties, low retention of experienced astronauts, and reluctance of astronauts or their families to commit to deployed duty. Additionally, the organization may end up launching crewmembers who are exhausted and frustrated even before the spaceflight begins. Needless to say, the same concepts apply to ground personnel in deployed positions.

To address this problem, we must work toward instilling in mission managers and crewmembers the idea that a mission begins when an astronaut is assigned to a flight, and that time for deployed training is part of the mission. We must also call for policies and procedures that counter the psychological demands on deployed people and their families. Usually this entails establishing two-way communications between home base, families, and deployed people; providing timely news from home; and addressing logistical issues such as storing home furnishings, frequency of home visits, or stocking libraries of recreational reading or videos. We'll also need to consider leave time, work-rest policies, ways to maintain connection with work events back home, recreation, and so forth. Organizations that regularly deploy people are familiar with these issues. But if the organization has little previous experience, we should begin developing these support countermeasures as soon as possible. We have to start early because organizations must develop policies from the ground up and negotiate integration with foreign host facilities.

Deployed people and the home organization will always misunderstand each other to some extent. A classic "we-they" friction can arise because they differ in their perspective, priorities, constraints, and available information. This "disconnect" occurs in any organization with remote operations, such as between orbiting crews and their ground controllers, mountain climbers and their base camp, submarine crews and topside personnel, and similar groups. Besides training to recognize when this inherent difference is compounding problems, we can reduce difficulties through two-way video and by rotating key managers through field locations.

Psychological Tools for Inflight: Given a well chosen and well prepared crew, countermeasures during the mission must provide them resources that support positive psychological health and performance. If they're enabled to work as an autonomous team, the crew can select from these resources to maintain their own well-being and productivity. For inflight tools especially, remem-

Class	Tool	Note
Training and strategies	Refresher training, personal strategies	Increase crew autonomy and self-management
Traditional support	On-board software and materials, resupply packages, audio, video and digital communications, library, music, exercise	Personalized, flexible array
Tracking	Self-monitoring, ground monitoring, software-based, mood, sleep, workload, cognition, audio/video conferences, family, electronic mail, air-ground content, voice-stress analysis	Early detection, self-monitoring
Intervention	Direct, indirect, electronic mail, video, sleep, workload	Open pre-existing relationships
Consultation	Commanders, crewmembers, mission annagement, flight surgeons, families	Pre-existing relationships

Table 7-3. Sample Inflight Countermeasures. We design inflight countermeasures to promote crew autonomy and to provide an array of behavioral resources.

ber our earlier discussion about the need for multiple, parallel paths to a support goal.

Training and strategies: This class of inflight countermeasures includes all electronic, software, and hardcopy methods of retrieving information for psychological training and strategies. Examples include dedicated computer-based text, books, interactive media, and Internet Web sites the crew can tap for review or for continuous learning. The content may be directed to the commander for leadership issues; to the crew as a whole for productivity, interpersonal, or air-ground issues; or to individual crewmembers for personal-adaptation, interpersonal, or family issues. It can also contain alternative strategies for typical and atypical scenarios, supplemental reference readings, and confidential personal strategies and reminders for each crewmember. The in-mission materials should seamlessly review and extend preflight training and preparation. Media for training and preparation must be technically compatible with on-board technology, pragmatic, and easy to use on orbit. We incorporate as many crewmember inputs as possible regarding content, interface, ease of set-up, use, and stowage in low-gravity conditions.

A nonbehavioral, continuous education capability, such as in geology, optics, etc., also can be provided. We may include more than one interest area and ensure they're connected to Earth-based mentors. During very long missions, such as an extended stay on the lunar surface or a Mars transit, we may also defer some non-critical technical training until scheduled periods during the mission. Doing so allows a reservoir of meaningful activity that serves as a psychological support during work underloads. Crewmembers can turn the amount of work up, down, or entirely off, depending on circumstances on board.

Traditional support: This class of countermeasures includes ensuring audio-video and electronic communications between families and crewmembers; providing on-board music compact discs and players, tape recordings, videos and video players, books, recreational software, calendars, and pictures from home; delivering packages from home through resupply; and similar amenities [Kozarenko and Holland, (forthcoming)]. To tailor these support resources, we meet with crewmembers before the mission to understand their priorities. We have as many different resources on board as possible, but emphasize ones crewmembers prefer. One astronaut may prefer to watch action videos; another may prefer to read books.

Unlike many mechanical systems, people are very dynamic—they often change during a mission. Mission events and extended confinement often change the crewmembers' emotional status and what psychological support they wish they had on board. For most people, strong preflight habits and preferences seem to continue in space, but some people change their preferences after settling into their new environment. For this reason, and because extended missions always require diversity, we don't give up a resource or capability on the strength of preflight preferences alone. We also provide for group recreation. Astronauts may feel uncomfortable watching a personal video or playing an individual software game if other crewmembers are still working. To preserve team cohesion, they may wait for a day when the whole crew can gather to watch a video or play a game.

News and information from home connect crews to familiar people and places. National and international news gives general events and trends, but the best news is about friends, family, and events in the crewmember's home town or home training center.

Street changes, house projects, weddings, children, visits from friends, pets' antics, musical recitals, and such rate right up there in interest with preparations for future launches, which astronauts have been assigned to which missions, who said what, and similar juicy tidbits. We provide news and information in multiple formats, such as text abstracts from major news networks, continuous news-summary services through an Internet connection, summaries read by friends in ground control and weekly chats with family, friends, and colleagues. Other methods are video segments from television, video abstracts from sporting events or international events, and so forth. The crew needs more than the bare facts. Because they're separated from society, they like to hear how the major news organizations are reporting mission events and how people they know and respect interpret or respond to these events.

Other on-board support has included musical instruments, an electronic "family album" of video clips, still pictures and audio messages from friends and family, software-based games, chess boards, plastic birds that sing, chocolate, autographed hockey pucks, Christmas trees and decorations for various holidays, and just about anything else that we can imagine. Some of the most cherished items have been sent to the crewmembers as a surprise, so some psychological support should be left unplanned. The most effective support is humor and companionship within the crew and from certain ground people who have a special relationship with the crewmember. It is important to allow for and enable these informal interactions [Holland, Vander Ark, and Curtis, 1997].

As mentioned earlier, hardware or software failures are almost inevitable, so we must build in redundancies. For example, we can place paperbound and software-based books on board for astronauts who like to read. We use the same approach for communications, music, and so forth. We design for imperfect on-board technology, use multiple parallel paths and modes, and assume that technical problems, scheduling pressures, and power reductions will occur. An example occurred on Mir 18, when the primary channel for air-to-ground communication was unavailable, and solar-array problems forced power to be conserved for critical systems. The psychological support group provided English-language news and social contact to the US crewmember through amateur radio.

Of all the psychological support available today, the most powerful method is communication with family and friends on Earth. Electronic mail is an extremely effective and popular method of crew-family communication. As technology advances, we should adopt it to increase privacy, make connections more direct, reduce intermediary parties, allow telephone messaging, and generally increase the system's flexibility. Then, crewmembers and families can communicate when they wish, not only when scheduled. But we back up this approach with lower-technology methods.

Individual preferences regarding communication frequency and mode vary widely. Frequency should be whatever is comfortable for the crewmember and families. Usually, some tacit or explicit understanding is based on what worked during past deployments, the age and needs of any children, and so forth. It's possible to have too much communication, just as it's possible to have too little. Too many sessions can leave the family and crewmember with little to say, or worse still, can be a distraction to the crewmember who is trying to adapt to separation. Crewmembers who become overly involved in activities back home have difficulty maintaining their focus, on mission tasks and

adjusting to life on the station or vehicle.

Multiple types of communication also allow us to accommodate personal preferences. Electronic mail is popular for short or long messages that are independent of time zones or scheduling constraints. Astronauts with young children usually enjoy two-way video conferences with the family so they can be a part of the rapid changes in their children and maintain a stronger connection with them. Amateur (ham) radio is excellent for family communications because it can be arranged quickly with little effort and usually has a strong signal. It also has packet and video features and the ability to patch a call through to any telephone around the globe. Unfortunately, it isn't private. Still, with multiple modes, crewmembers and families can use each type as they see fit.

Crewmembers will be better able to focus on their mission if they know someone is helping their families back home. We can route inflight support for crew families through a family-support office, behavioral specialists, flight surgeons, unassigned astronauts, and spouse-support organizations. All of these channels have been used, usually in parallel, to ensure that the crew families receive reliable mission information, remain connected to the astronaut, and understand psychological and adjustment issues pertaining to separation and homecoming. These communications also inform families about upcoming events that involve them and support them in maintaining normal family life.

Tracking: Because the psychological health, well-being, and performance of the crewmembers and the team directly affect mission success, we want to intercept any significant downturns as early as possible. Everyone has ups and downs in mood and performance, but we should design tools in this class to capture the mission-significant changes or trends. Tracking tools should be part of a process in which crewmembers participate in monitoring themselves and managing their own health and performance. We can keep the tools relevant while avoiding being perceived as intrusive or voyeuristic and promoting crew autonomy. In the past, tools for monitoring have included audio conferences with flight surgeons, electronic mail exchanges, on-board, software-based cognitive tests and questionnaires concerning sleep, mood, satisfaction with mission progress, team cohesion, etc. The Russians have also used voice-stress analysis, video analysis, embedded measures of performance, and error tracking.

The pedigree issues for tracking tools are similar to those discussed earlier for selection and training. Sensitivity and reliability are crucial, as is the relationship of the changes to health and work outcomes. It's not enough to reliably detect changes in workload, mood, sleep, cognition and so forth; we must be able to demonstrate linkages between these changes and important outcomes for the mission or the crewmember. For example, showing that sleep deprivation decreases reaction time is useless to a mission commander without hard evidence demonstrating how specific decreases affect performance on a specific mission task. We should look closely at this issue and consider precursor activities, such as analyzing critical tasks and scenarios, to bolster a tool's pedigree. For health-related outcomes, we make sure flight surgeons participate in forming tracking tools and what they measure. Changes in mood, workload, sleep, satisfaction and so forth may cause, precede, or accompany behavioral and medical dysfunctions. These changes almost always have multiple origins, driven by time or events [Wood and Holland, 1993]. In any case, we strive for the fewest and briefest tracking tools that serve the purpose and try to involve crewmembers in using the tools for self-tracking and self-

management.

In an integrated design, we track topics and issues that we've already considered during preflight selection, training, and preparation. That is, the data generated through tracking should address the same issue the crewmembers became familiar with during training and preparation. Tracking information permits them to know about potential disablers and to modify their strategies for coping with these conditions and events.

Intervention: Intervention is used only when tools for selection, assembly, training, preparation, support, self-management, and team-management have proven insufficient. By *intervention*, I mean any real-time effort to alter a crewmember's psychological status or ability to work, or to change the climate and process within the crew or between the crew and ground team. The person intervening may be a behavioral specialist, a close friend or family member, mission manager, inflight commander, crew medical officer, and so forth. I can't cover in this chapter all intervention approaches and issues, but certain capabilities will enable effective intervention. The main capability is private communication between the crewmembers and the person who intervenes. Private conversations between Earth and space are possible only through a direct, encrypted channel for audio, audio-video, telemedicine or electronic mail. In the past, this kind of channel has been very difficult to achieve, but advances in telecommunication now make it possible. Even with this, however, we have to go to great lengths to ensure that it's truly private. If the crewmembers don't trust the system, they won't use it or will shy away from discussing sensitive issues on it.

Other types of interventions can include increasing or decreasing a crewmember's workload, such as whenever an EVA approaches, or helping balance work activities that compete for crew time, such as science experiments versus station maintenance. We can also adjust sleep and circadian cycles by reducing the frequency or extent of sleep shifting, discuss generic strategies with the whole crew, and so forth.

Consultation: This last set of countermeasures usually means informing or providing recommendations to the crew, family, or organization. Often, we can help by being a sounding board for mission managers, families, commanders, ground personnel, and flight surgeons. Sometimes informal hallway discussions can be as important as formal meetings or written position papers. Extended missions require much more psychological information than short missions do. Events and changes, such as delay of a return vehicle, may raise mission-management issues and families may experience life events, such as the death of a grandparent, that can affect the crewmember.

Psychological Tools for Postflight: It is a myth that the mission starts and ends at launch and landing. In reality, the psychological demands of the mission begin when the crew is assigned and, for lengthy missions, end several months after landing. Crewmembers, their families, and ground personnel must respond to a number of postflight demands. Following a brief mission, the physical and psychological demands are relatively light and center on falling back into the activities of routine life. Following a long flight, however, the adaptation issues are more significant and warrant more attention. Thus, I'll talk mainly about tools for extended missions.

Although the end of a long flight is a time for celebration, subtle pressures and difficulties may trouble uninformed crews and families. For example, toward the end of a long flight, crewmem-

Class	Tool	Notes
Support	Repatriation and adaptation, crewmember, family, leave time, reconnection with work	Mission demands continue
Tracking	Formal and informal	Multiple debriefings and tagups
Consultation	Crewmember, family and management	Realistic expectations of self and others

Table 7-4. Sample Postflight Countermeasures. Postflight countermeasures should address continuing psychological demands on the crewmembers and their families. The mission is not over at landing.

bers and their families begin to imagine what life will be like after landing; sometimes, reality doesn't meet their expectations. During a long separation, spouses take on tasks they normally don't do and sometimes want to restructure roles and responsibilities with the crewmember after the flight. The crewmember may be completely surprised by this and may have a very different view of what the roles should be. A crewmember may feel less necessary in the family scheme, or a spouse may feel less necessary or unappreciated. Sometimes a crewmember with a very young child is dismayed to find that the child needs a few days to re-establish the relationship. In some families, spouses may expect crewmembers to reassume certain obligations even though the crewmembers are too fatigued take on those tasks for some time. In other cases, crewmembers or families are surprised and disappointed that postflight data collection and public appearances take crewmembers away from home almost as much as during the flight. These are just a few examples of postflight pressures.

Postflight countermeasures should include two or three formal debriefings of crewmembers over about two months. We debrief as soon as possible-but no later than three days-after landing. Crewmembers are considerably more open and able to articulate emotions and sensitive issues during this time than later. We follow with another debriefing within ten to fourteen days and a third around 30-40 days after landing. The discussions check on the crewmember's psychological status and assimilation into the home and office, the level of the postflight workload, and so forth. We can also gather recommendations about the effectiveness of the countermeasures and strategies for selection, training, and support. In most cases, meetings with the spouse are also helpful.

More productive than formal meetings are the informal interactions among behavioral specialists, crewmembers, and families. Most astronauts and spouses appreciate the interest shown in their welfare and the effort made to support their smooth return to a normal home and work life. Following a long flight, crewmembers generally return to normal physical functioning (muscles, balance) sooner than they return to their prior psychological functioning. In particular, crewmembers may not return to normal energy levels for several months after landing. Crewmembers have drained emotional reserves during the flight and are still expending energy with postflight tasks and readaptation. They and their families may be surprised that "recharging" takes longer than expected.

Realistic policies about leave time also are extremely powerful tools for rehabilitation. There is no set formula for how much leave time is best because people vary in the length of time they want to be away from work. But a rule of thumb is about ten days' vacation for every month away from Earth, to be taken within six months after landing. If programs make this time available, then the crewmember, the family, and flight surgeon can determine the timing and exact amount.

7.3 Levying the Design

To make the selection, training, and other countermeasures happen, we must translate the design into the mission planners' language and insert it into the controlling mission documents. For now, this means translating the countermeasures into detailed mission requirements. Requirements, in the mission world, are the bedrock specifications that spell out for the program exactly how these countermeasures are to be implemented. Requirements are less concerned with "why" and are more concerned with "what" and "how." This includes the procedures, hardware, software, on-board materials, crew training time, communications, and other resources needed for each countermeasure planned for before, during, and after flight.

These details must then be incorporated officially into controlling mission documents. Some documents require only brief, general statements, such as "A psychological assessment will be part of crew selection." Others will need details, such as the precise number of crew hours required for confined team training, the pattern of those hours, and at what point in preflight training they must occur. We must also state the learning objectives, locations, materials needed, criteria for success, ways to measure results, safety issues, what other parts of the organization must do, and so forth.

As this book's table of contents indicates, many other groups levy requirements on the mission. Often, they conflict, so mission planners must weigh the costs and benefits of accepting one over another or of asking the requirement owner to come up with some other solution to a problem. This challenges us, as requirement owners, to differentiate between hard requirements and guidelines. We consider requirements to be what we can't compromise without strongly affecting the mission's objectives, including the crewmembers' health, well-being, or performance. Guidelines are important but more flexible descriptors in the design. In some cases, we may have to develop an alternative countermeasure. For example, constraints on time, volume, or funding could make it impossible to carry out our original concept. Requirements and documents that control mission planning and execution are the only way many people outside the behavioral community will know about and understand the psychological design. If we don't include important aspects of the design in these documents, it's as if they never happened. On the other hand, psychological activities written into the final version of these documents often become part of the traditional, accepted flow of mission activities for later programs. Consequently, the tedious documentation work for one mission can sometimes lead to a positive, long-term shift in the organization's attitude toward, and use of, behavioral resources in general.

In addition to generating requirements, we must establish relationships with other parts of the organization that will help carry out our design. For example, people in the telecommunications group need to know about the requirements we are submitting and understand what their role will be in crew-family communications. They can suggest the most effective procedures and usually can improve the countermeasure when they understand the reasons behind it. During the Shuttle-Mir program, the telecommunications people understood the importance of their discipline in supporting the astronauts' well-being and went to great lengths to ensure communications. They improved our countermeasure in several ways, including tapes of the audio-video sessions for families to take home, remote cameras capturing images of familiar outdoor loca-

tions, special video features enabling crewmembers to get better views of active children and pets, video uplink of sports events, and more.

Similarly, for any multinational program, we need to coordinate and collaborate with international counterparts when levying the design. Assuming we've established productive working relationships while developing the design, behavioral designers can support one another very effectively while carrying out requirements. Having agreement across nations about goals, countermeasure procedures, importance, required resources, and so forth is more powerful than being the lone voice in an agency. Differences in resources or customs between space agencies occasionally create differences in the inflight support, such as the amount of electronic mail forwarded to crewmembers, how much audio or video they can access, and so forth. In the interest of crew harmony and parity, all international partners should provide similar support resources during a flight. The design is complete when we've incorporated it into the appropriate documents and established relationships to carry it out.

7.4 Conclusion

The topics described in this chapter are "core topics" which apply to most space missions regardless of duration. However, long-duration missions are qualitatively as well as quantitatively different from short ones. Just as six-month station tours present greater psychological challenges than brief Shuttle flights, significantly longer missions such as to Mars will require radical rethinking of demands and countermeasures. The limitations of current propulsion and communication technologies will drive increased crew autonomy. The increased length of planetary exploration and lunar colonization tours will require richer and more normalized living and working environments. It will be necessary for designers to establish environments which support the normal evolution of professional and social lives, meet a broader range of human needs, and enable individuals to successfully cope with more complexity. However, the prime mandate will continue to be sustaining and promoting psychological health, well-being, and performance.

In order to transition successfully to long missions, organizations must fully incorporate the human system into their early mission planning. It is much easier to learn this from good crew health and satisfying mission outcomes than it is to learn it from a critical performance error, a crewmember with a significant clinical condition, or a premature mission termination.

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