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Resilience and Growth in Long-duration Isolated, Confined and Extreme (ICE) Missions

A Literature Review and Selection, Training and Countermeasure Recommendations

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Executive Summary

This report is intended to satisfy the requirements of solicitation NNJ13487837QA: "Individual Growth and Resilience". This report is presented in two parts: a review of existing literature and an operational assessment of resilience specifically in the context of long-duration spaceflight. The literature review begins with a description of the conceptual development of resilience and growth. This is followed by a review of empirical evidence demonstrating the effects of protective factors that promote resilience and growth, first within the broader psychological literature, then with regard to research conducted in isolated, confined and extreme (ICE) environments. Conclusions from the literature review include:

- Protective factors (e.g., effective cognitive appraisal and coping, optimism, self-efficacy, social support) play a central role in individuals' ability to demonstrate resilience and growth when faced with adversity and stress.

- Evidence on the effects of protective factors within the ICE literature largely aligns with that found in the broader literature. Specifically, perceived social support, problem-focused coping and positive cognitive reappraisal have been consistently shown to contribute to resilience and growth.

- Additional evidence regarding the effects of protective factors in ICE settings runs counter to what has come to be expected within the broader literature. That is, some ICE research has shown avoidant coping to be a viable approach to maintaining psychosocial functioning, while social support-seeking coping behavior has been shown to be negatively related to resilience.

- Measuring the presence of protective factors pre-flight may prove useful in both differentiating otherwise highly and similarly qualified candidates for long-duration ICE missions, as well as improve the collective resilience and potential for growth among ICE crews.

- Consideration of similarity and compatibility among crewmembers on psychosocial characteristics (e.g., personality and values) may reduce sources of conflict among crews during long-duration missions and lead to greater levels of resilience and growth.

- Resilience-building training programs and countermeasures have been shown to be effective among a wide range of non-ICE, at-risk populations, suggesting these programs may also be effective among various types of ICE personnel. However, a number of characteristics have been demonstrated to influence program effectiveness, including: minimizing barriers resulting from mental health stigma and supplementing primary training programs with mission control and/or family support training. Resilience and growth are also relevant not only to crewmembers, but can also have important implications for mission controllers and family members who must also adapt to unique stressors associated with long-duration spaceflight missions.

Results from the interviews with subject matter experts (SMEs) aligned well with the general conclusions of the literature review. Common themes identified through these interviews include:

- SMEs defined resilience within the long-duration spaceflight context as both "sustaining" functioning in the face of continuously experienced stressors (e.g., ambient noise, monotony) and "bouncing back" from prospective acute stressors (e.g., emergency situations).

- Group and interpersonal aspects of resilience have increased importance in isolated and confined environments. Even basic conceptualizations of resilience involve a strong interpersonal component, with resilient crews being those in which each individual member understands his or her role and responsibilities, understands and supports crew goals and objectives, has trust and confidence in his or her fellow crewmembers, and is willing to help and support others.

- Previous literature has suggested that mission control can play a central role in crewmember health during spaceflight missions (e.g., Brady, 2005), and the importance of mission control to crewmember resilience was clearly demonstrated in SME responses. SMEs indicated mission controllers can support crewmember resilience, for example, by acting in an honest, trustworthy, and efficient manner, and by understanding and being sympathetic to the experience of stressors associated with spaceflight.

- Family (and close others) also play a crucial role in the resilience of crewmembers throughout pre-to-post-mission phases. There is no "magic bullet" specifically regarding how families can best support crewmembers' resilience. Instead, SMEs suggested the "how" typically comes down to specific family dynamics and expectations. However, families can demonstrate support (however appropriate), keep crewmembers informed about family issues, and not introduce additional and unnecessary stress to support crewmembers' resilience.

SME responses provide material for specific recommendations for enhancing crew resilience. Recommendations for enhancing team aspects of resilience include:

- Providing training aimed at maintaining and developing resilience-based protective factors to crewmembers, potentially as interactive, self-administered, computer-based modules that can be completed pre-mission or during the transit phase of a long-duration mission. Computer-based resilience training programs exist, but the validity of these remains somewhat unclear. Sophisticated and interactive training modules need to be developed and evaluated in analogue ICE settings.

- Placing greater emphasis on crew compatibility. Specifically, selection procedures should consider the potential compatibility of crew members. Importantly, we do not suggest compatibility analyses to be carried out strictly on the basis of individual similarity. Instead, we suggest identifying characteristics detrimental to crew compatibility. For example, it may be beneficial to identify individuals who cannot

tolerate potential personality and character quirks in others, and eliminate these individuals from consideration.

- Providing ample opportunity for crews to familiarize themselves with and adjust to one another prior to long-duration ICE missions. This was one of the most cited themes in SME responses regarding ways to enhance resilience. SMEs offered multiple recommendations, and NASA will need to determine the most effective and efficient ways of achieving this goal. NASA will have to determine how much time is necessary for teams to establish sufficient familiarity. Also, NASA will need to determine which avenues (e.g., formal training, informal team-building, or both) are most effective at promoting familiarity.

Recommendations regarding mission control include:

- Increasing familiarity between crewmembers and members of mission control. Much like recommendations to increase familiarity among crewmembers, developing greater familiarity and more personal relationships between crewmembers and mission controllers should enhance mutual respect, open communication, and trust. Again, NASA will need to determine the most effective and efficient ways of achieving this goal, including the amount of time needed to sufficiently foster familiarity and the avenues through which to promote familiarity.

- Providing psychoeducational training to mission control so that mission controllers better understand obstacles and stressors the crew will be subjected to during a long-duration mission, identify negative effects of stress and stress-related symptoms among crewmembers, and efficiently communicate with crewmembers when either or both sides are experiencing elevated levels of stress.

- Maintaining and enhancing psychological health and resilience among mission controllers will likely enhance crewmember resilience, or at least minimize threats to crewmember resilience associated with mission control relations. Therefore, it would be beneficial to develop countermeasures and training for use among mission controllers. It is understood that psychoeducational training focused on the above issues is currently being developed for mission controllers. This training should be consistent with the training to be given to crews and should undergo rigorous evaluation prior to deployment to determine effects on mission controller and crew perceived stress and communication effectiveness.

Recommendations regarding crewmembers' families include:

- Providing family and spousal training prior to long-duration missions to establish expectations for familial communication and support and prepare the crewmember and his/her family for the changing responsibilities during the long-duration mission. This training should be consistent with training given to crew and mission control.

- Providing family members support throughout the long-duration mission and psychoeducational training to prepare them to support crewmembers' readjustment to normal living, post-mission.

Recommendations for crewmembers, mission control and families include:

- Providing consistency in themes and common language across countermeasure, training, and other resilience-based efforts implemented among crews, mission control, and families in order to maximize the effectiveness of any specific effort.

Maintaining the psychosocial health of individuals in isolated, confined, and extreme (ICE) environments represents a major concern of researchers and agencies focused on long-duration spaceflight (e.g., Davis, Fogarty, & Richard, 2008; Dawson, 2002). The concepts of resilience—successful adaptation to adversity (e.g., Luthar, Cicchetti, & Becker, 2000)—and growth—positive change in an individual, post-adversity (Linley & Joseph, 2004, 2005)—have become centerpieces in prevention-focused research, and both have the potential to inform preventive health initiatives adopted by NASA. The concepts of resilience and growth have been applied and tested across the fields of clinical, developmental and education psychology (e.g., Bonanno, 2004; Masten & Garmezy, 1985; Werner & Smith, 1992), organizational and military psychology (e.g., Casey, 2011; Meredith et al., 2011; Wald, Taylor, Asmundson, Jang, & Stapleton, 2006; Youssef & Luthans, 2007), and psychiatry, neurology and medicine (e.g., Goldstein & Brooks, 2013; Rutter, 2000; Wu et al., 2013). Similarly, these concepts have been examined among a range of populations that face various levels and types of adversity, including developmental risk factors (e.g., low socioeconomic status, child neglect and substance abuse, community violence; Garmezy, 1991; Rutter, 1979; Werner & Smith, 1992) and acute traumatic experiences (e.g., Bonanno, Rennicke, & Dekel, 2005; Bonanno, Galea, Bucciarelli, & Vlahov, 2006, 2007; Eid & Johnsen, 2002; Qouta, Punamäki, Montgomery, & El Sarraj, 2007). Recently, evidence has begun to suggest that resilience and growth can be developed, which has made efforts aimed at enhancing these characteristics quite popular as a means of prevention.

Given the many potential sources of adversity individuals may face during long-duration spaceflight missions, resilience and growth represent concepts likely important to overall mission success, as well as to the positive psychosocial functioning of crewmembers prior to, during, and following long-duration spaceflight. However, these concepts have received very limited

attention within ICE settings to date. The present report seeks to contribute to knowledge in this area in three ways. The first objective is to provide a review of existing resilience and growth theory, research, and practice within the broader literature, with a focus on resilience-based psychosocial protective factors (e.g. effective coping skills, self-efficacy, social support). The second objective is to provide a review of the evidence linking protective factors to resilience and growth in ICE contexts. The final objective is to integrate existing theory and evidence with the results of interviews conducted with various subject matter experts (SMEs; e.g., former astronauts, flight director, NASA physician) in order to provide recommendations for practice (e.g., selection, training, countermeasures) and future research needs.

Part I: Review of Resilience and Growth Literature

Four Waves of Research: A Historical Perspective

To inform efforts to enhance resilience and growth in long-duration and other ICE settings, it is beneficial to begin by providing a historical perspective of the development of resilience theory through four distinct waves of research (Masten, 2007; O'Dougherty Wright, Masten, & Narayan, 2013). Although researchers have long studied the risk factors that lead to the development of mental disorder and pathology, the first wave of resilience research arose through the observations of those who demonstrated the ability to successfully adapt to such risk factors and maintain healthy functioning (e.g., Anthony, 1974; Werner & Smith, 1982, 1992). Specifically, this initial wave of resilience research focused on identifying the characteristics that differentiate those who successfully overcome adversity from those who do not. The result of the first wave of resilience research was a comprehensive list of individual, social and environmental protective factors that were shown to contribute to resilience with considerable levels of consistency (see Table 1; see Luthar et al., 2000; Werner, 1995). The identification of

these factors provided the foundation of resilience theory. As such, these factors have continued to play an important role in our understanding of resilience throughout subsequent waves of research (Masten & O'Dougherty Wright, 2010), and they are a main focus throughout this review.

Table 1. *Examples of Protective Factors*

Individual Characteristics
Social and adaptable temperament
Cognitive ability
Problem solving skills
Self-esteem/efficacy/confidence
A sense of meaning in life
Effective communication skills
Internal locus of control
Motivation to improve self/situation
Ability to manage emotions
Optimism/hope/positive outlook
Trust in others
Flexible/creative in utilizing skills
Social Characteristics
Ability to form and maintain positive relationships
Close relationship with one or more individuals
Stable and supportive home environment
Religious or social affiliations
Environmental Characteristics
Socioeconomic advantage
Access to good health care
Safe community environment (e.g., low violence)
Employment opportunities

Examples of protective factors obtained from O'Dougherty Wright et al. (2013) and Earvolino-Ramirez (2007).

The second wave of resilience research sought to understand "how" these protective factors contribute to resilience (Luthar et al., 2000; Masten, Best, & Garmezy, 1990; Richardson, 2002). This wave of research marked evolution in the field, as researchers set out to better understand the dynamic process by which individuals use protective factors to positively adapt to

adversity (e.g., Luthar et al., 2000). For example, this research aimed to identify mechanisms, such as methods of cognitive appraisal and coping (e.g., Compas, Connor-Smith, Saltzman, Thomsen, & Wadsworth, 2001), that mediate the path between experiencing adversity and demonstrating positive adaptation (Luthar et al., 2000; Masten, 2007; O'Dougherty Wright et al., 2013). In addition to the process-focus, greater emphasis was placed on the study of how individual, social, and environmental characteristics interact to enhance or hinder positive adaptation (e.g., Richardson, 2002). Finally, this research contributed to knowledge regarding how protective factors, at the individual level, can be more or less effective in different contexts (e.g., social, academic) and in response to different forms of adversity (e.g., acute trauma, sustained stressful work conditions), as well as how resilience fluctuates over time (e.g., Masten & Garmezy, 1985; Rutter, 1985, 2000; see O'Dougherty Wright et al., 2013).

Researchers involved in the third wave of resilience research drew on knowledge created during the first two waves to craft interventions designed to develop and enhance individuals' capacity to adapt positively to adversity (e.g., Masten, 2007). To date, resilience-building interventions have targeted a wide range of protective factors including: self-esteem/self-efficacy (e.g., Botvin, Schinke, Epstein, & Diaz, 1994; Davidson, Feldman, & Margalit, 2012), hope and optimism (e.g., Cheavens, Feldman, Gum, Michael, & Snyder, 2006; Franklin & Doran, 2009), problem solving (e.g., Zautra et al., 2008), effective coping ability (Adler, Bliese, McGurk, Hoge, & Castro, 2009; Williams et al., 2004; Williams et al., 2007) and interpersonal relations and communication (e.g., Kowalenko et al., 2005; Roosa, Gensheimer, Short, Ayers, & Shell, 1989). Resilience-building interventions have yielded varying levels of effectiveness, with a number of variables moderating their impact. These characteristics are discussed later in this review.

The fourth wave of resilience research has expanded focus to developmental, genetic and neurological characteristics as possible protective factors (see Masten, 2007; see also Masten & O'Dougherty Wright, 2010; O'Dougherty Wright et al., 2013; Wu et al., 2013). For example, fourth wave research has assessed the interactive effects of genetic and environmental factors in predicting resilience (e.g., Brody, Beach, Chen, & Murry, 2009; Kim-Cohen & Gold, 2009), and the effects of dopamine on emotional processing and vulnerability to stress and trauma (Blasi et al., 2009; Ptáček, Kuželová, & Stefano, 2011). As research conducted under this wave continues, a more comprehensive and increasingly complex and dynamic model of the antecedents, conditions, processes, and consequences relevant to resilience theory is beginning to emerge. Undoubtedly, this research will yield important information for understanding long-duration spaceflight; to date, however, little-to-no research in this domain has been applied specifically to ICE settings.

Resilience: Definition and Conceptual Issues

Broadly, resilience is defined as "positive adaptation to adversity" (Goldstein & Brooks, 2013; Luthar et al., 2000; Rutter, 2000). Scholars have traditionally conceptualized resilience as relevant only under conditions of considerable threats to psychological health, for example in an abusive environment (e.g., Werner & Smith, 1992) or when one is exposed to catastrophic/traumatic events (e.g., Bonnano, 2004). However, resilience has more recently come to also be described with regard to comparatively mundane forms of adversity, such as stressors that are experienced on a daily basis (e.g., interpersonal quarrels; Masten, 2001). Researchers have also debated what constitutes positive adaptation (e.g., Naglieri, LeBuffe, & Ross, 2013; Zautra, Hall, & Murray, 2010). For example, some scholars have suggested resilience involves maintaining normal functioning (Bonanno, 2004), while others have

suggested positive adaptation involves “bouncing back” (e.g., Cornum, Matthews, & Seligman, 2011). Going a step further, scholars have emphasized adversarial or posttraumatic growth (Linley & Joseph, 2004, 2005; Tedeschi, Park, & Calhoun, 1998), which represents positive change resulting from the experience of adversity. Although believed to be distinct, resilience and growth occupy proximal positions in the nomological network and share many of the same protective factors (see Tedeschi & Calhoun, 2004).

Despite the generally accepted definition of resilience, the issues are described above in order to demonstrate the subtle conceptual differences that exist regarding resilience and growth constructs as function of the context in which they are studied. For example, among children whose long-term developmental trajectories have been of greatest interest, adversity may be most prominently reflected in deeply embedded risk factors, such as caregiver quality or neighborhood crime rates (Garmezy, 1991; Werner & Smith, 1982, 1992). Conversely, among adult and military populations, adversity may be best reflected in responses to specific traumatic events (e.g., Bonanno et al., 2007).

For the purposes of this review, our discussion of adversity broadly reflects the full range of potential sources of stress or trauma for which crewmembers are at risk prior to, during, and after an ICE mission. Moreover, we consider positive adaptation in ICE environments as either sustained psychosocial functioning or “bouncing back” (i.e., preventing the development significant psychosocial health deficits). That is, sustained functioning likely represents resilience in response to fairly common types adversity (e.g., short-term radio communication blackouts), while “bouncing back” likely represents resilience in response to substantial adversity (e.g., long-term isolation). On the other hand, growth is represented by instances in which post-adversity development establishes a higher baseline level of normal functioning.

It is also important to note that, although resilience is often conceptually defined as a complex and dynamic process by which protective factors mediate the relationship between the experience of adversity and positive adaptation (e.g., Luthar et al., 2000; O'Dougherty Wright et al., 2013), this is typically not how the construct has been operationalized empirically. Instead, resilience has often been operationalized as an outcome—for example, the absence of symptomatology or the presence of well-being—predicted by protective and risk factors (e.g., Bonanno et al., 2006, 2007; Maguen et al., 2008; Werner & Smith, 1982; see also Werner, 1993 for a review of operationalizations of resilience throughout first and second wave resilience research). Incongruence between conceptual and operational definitions of resilience may be largely due to practical limitations of research designs. However, the operational definition (i.e., resilience as an outcome) aligns well with resource-based models in the broader adaptation, coping, and stress literatures, which emphasize that greater resources (i.e., protective factors) increase the likelihood of successfully coping with or adapting to stress (i.e., demonstrating positive adaptation; see Hobfoll, 2002). This has led many scholars to conclude that resilience and growth can represent both a process *and* an outcome (e.g., Zautra et al., 2010; Tedeschi & Calhoun, 2004). While acknowledging the potentially complex process of positively adapting to adversity, this approach also does not ignore direct empirical evidence demonstrating the effects of protective factors on psychosocial outcomes. Taken together, this literature review tends to describe resilience and growth through the effectiveness of protective factors at contributing to resilience-based outcomes. More specifically, this review emphasizes those factors which are psychosocial in nature.

Protective Factors, Resilience, and Growth

Protective factors remain central to the empirical study of resilience and growth, and multiple meta-analyses have been conducted on their effects in contributing to resilience- and growth-relevant outcomes. One such meta-analysis (Lee et al., 2013) examined the relationship between self-reported scores on measures of various protective and risk factors and self-reported scores on the Connor-Davidson Resilience Scale (CD-RISC; Connor & Davidson, 2003) and the Resilience Scale (RS; Wagnild & Young, 1993). Results indicate that self-reported resilience scores related considerably to scores on measures of protective factors: self-efficacy (r = .61), positive affect (r = .59), self-esteem (r = .55), life satisfaction (r = .43), optimism (r = .42), and social support (r = .41). Self-reported resilience scores related less strongly to risk factors: depressive symptoms (r = -.39), anxiety symptoms (r = -.38), perceived stress (r = -.36), posttraumatic stress disorder (PTSD) symptoms (r = -.29), and negative affect (r = -.27). Conclusions based on these findings are somewhat limited by the likely presence of common method bias in the primary studies meta-analyzed (Podsakoff, MacKenzie, Lee, & Podsakoff, 2003). Nonetheless, this meta-analytic evidence underscores the potential importance of protective factors to understanding resilience.

Other meta-analytic evidence has demonstrated the effects of protective factors on criteria suggesting the presence of resilience and growth. For example, among maltreated children (<18 years old), temperament/personality traits (r = .20) and cognitions (r = .16) were shown to be the strongest indicators of positive adaptive functioning, while self-perceptions (r = .09), interpersonal characteristics (close familial relationships, r = .08; close non-familial relationships, r = .07), and environmental characteristics (i.e., community resilience, r = .06) showed somewhat weaker effects (Nasvytienė, Lazdauskas, & Leonavičienė, 2012). Overall,

these effect sizes suggest only weak relationships between protective factors and resilience-based outcomes. Among adults (≥18 years old), Lamp (2013) has demonstrated stronger meta-analytic relationships between protective factors (optimism, self-efficacy, self-esteem, social support, spirituality) and resilience-based outcomes. Specifically, self-efficacy and self-esteem were the strongest predictors of adjustment to trauma (r = .44 and .41, respectively) and psychological adjustment (r = .58 and .52), while spirituality (r = .31) and social support (r = .21) significantly predicted posttraumatic growth.

Research focused specifically on the relationship between protective factors and growth (e.g., benefit finding) indicates trivial effects for demographic characteristics, while larger effects were found for various psychosocial protective factors: positive reappraisal coping strategies were most strongly associated with benefit finding (r = .38), followed by optimism (r = .27), acceptance coping (r = .20) and religiosity (r = .17; Helgeson, Reynolds, & Tomich, 2006). Interestingly, the findings of Helgeson et al. also indicated denial coping strategies to positively relate to benefit finding (r = .16). In turn, benefit finding was shown to significantly, positively relate to subjective well-being (r = .22) and significantly negatively relate to depressive symptoms (r = -.09). It should be noted that benefit finding was also significantly, positively related to intrusive-avoidant thoughts (r = .18). A second meta-analysis (Prati & Peitrantoni, 2009) examining the contribution of protective factors to posttraumatic growth found posttraumatic growth to be most strongly influenced by the use of religious and positive reappraisal coping strategies (r = .38 and .36, respectively), while the effects of social support, optimism, spirituality, and social support-seeking coping strategies on posttraumatic growth ranged from r = .23 to .26. The weakest effect was found for acceptance coping strategies (r = .17).

The relationships between protective factors and hardiness, a personality characteristic with strong conceptual ties to resilience and growth, have also been demonstrated meta-analytically (Eschleman, Bowling, & Alarcon, 2010). Hardiness related most strongly to sense of coherence (r = .50), self-esteem (r = .43) and optimism (r = .43). Hardiness was found to relate weakly-to-moderately with perceptions of various sources of support, ranging from r = .32 (family support) to r = .21 (friend support). Hardiness was also shown to relate negatively to reports of stress (e.g., life stress, r = -.25; work stress, r = -.26) and adverse psychosocial outcomes (e.g., psychological distress, r = -.39; depression, r = -.41; PTSD, r = -.47; psychological maladjustment, r = -.29) and positively to indicators of well-being, ranging from r = .28 (happiness) to r = .50 (life satisfaction). Finally, hardiness was shown to have small-to-moderate effects on performance-related indicators, including: job and school performance (r = .17 and .21, respectively) and group cohesion (r = .26).

Cumulative Protection

The above evidence indicates that individual protective factors have typically shown small-to-moderate relationships with resilience- and growth-based outcomes. However, protective factors are unlikely to exist or function independently, and often complex interactions can lead to greater effects (O'Dougherty Wright et al., 2013). Moreover, a strong standing on one or more protective factors likely contributes to the development of other protective factors, a phenomenon that Waller (2001) refers to as the "pile up" effect. For example, receiving strong social support may have important effects on individuals' self-esteem, hope and optimism. High self-esteem, hope and optimism likely affect individuals' cognitive appraisals of stress and adversity, as well as subsequent strategies for coping. Effective coping, in turn, likely improves

self-esteem and individuals' interpersonal confidence, which can lead to stronger social support networks.

The cumulative effects of protective factors on positive adaption to adversity and post-adversity growth have been shown to be quite substantial. For example, primary evidence using multiple regression techniques has demonstrated coping, cognitive outlook, emotional expression and social support to account for more than a third of the variance in individuals' well-being after the September 11th terrorist attacks (Butler et al., 2009). Among former Ugandan child soldiers, a series of individual, social, and environmental protective factors accounted for over 43% of the variance in subsequent resilient functioning (Klasen et al., 2010).[1] Evidence such as this suggests protective factors have important consequences for individuals' ability to maintain healthy functioning, "bounce back", and grow as a result of experiencing adversity. What remains to be examined in depth, however, are the effects of protective factors on resilience and growth-related outcomes among individuals experiencing the unique adversities associated with ICE environments.

Resilience and Growth in ICE Environments

ICE environments are characterized by elevated levels of adversity and stress. Although resilience is not a term often used within the ICE literature, empirical research has assessed the effects of protective factors on indicators of positive adaptation and psychosocial functioning in ICE environments. The protective factors most commonly studied within ICE settings have been social support and various coping strategies. Much of the evidence regarding the relationships between protective factors and positive adaptation and psychosocial functioning in ICE environments aligns with that found within the broader resilience literature. However, some

[1] Amount of variance was estimated using Nagelkerke's pseudo R^2 due to the dichotomous nature of the resilient functioning variable used by Klasen et al. (2010).

unique relationships have also emerged. In these cases, possible explanations for these findings are discussed.

Effects of Protective Factors on Indicators of Resilience

Social support. Among Antarctic winterers, researchers have observed a stronger negative relationship between concurrently measured depressive symptoms and social support satisfaction after an Antarctic stay, as opposed to before (pre: r = -.32; post: r = -.44). This may suggest that the importance of social support in deterring depressive symptoms was greater under adverse ICE conditions than under normal living conditions prior to the ICE mission (Palinkas & Browner, 1995). Further evidence from Antarctic winterers has demonstrated that those with strong social networks are also more likely to be rated by peers and supervisors as well-adjusted to Antarctic station living (Palinkas & Johnson, 1990). Interestingly, social isolation was not shown to be the cause of poor adjustment ratings by peers and supervisors. Observations from the broader resilience literature indicate that the size of social support networks is not as important as support quality (e.g., Anthony, 1974; Richardson, 2002). Thus, winterers viewed as socially isolated may have lacked robust social networks, but had one or a few sources of social support of sufficient quality to allow for successful adjustment to Antarctic station living. Additional evidence related to social support as a protective factor comes from an international Arctic expedition, wherein perceived friendliness, an aspect of social support, among a Soviet-American expedition crossing the Bering Strait was positively related to perceptions of team emotional cohesion (r = .72) and reported frequency of helping behaviors (r = .69; Leon, Kanfer, Hoffman, & Dupre, 1994).

Evidence of the importance of social aspects as protective factors has also been demonstrated among spaceflight crews. For example, comparisons of spaceflight crews to that

of a normative Earth-based sample on perceptions of social support and social functioning showed that supervisor and leader support were higher, albeit non-significantly, among spaceflight crews (Kanas et al., 2001a). The study also found significantly greater perceived cohesion among crewmembers than among the normative sample. Moreover, evidence indicates a significant relationship between leader support and cohesion among both Shuttle/Mir mission control personnel and crewmembers, a finding that has been replicated among samples of ISS mission controllers and crewmembers (Kanas et al., 2006). Among Shuttle/Mir and ISS crewmembers, Kanas and colleagues (2001b; Kanas et al., 2006) also showed scores on the supervisor support scale to be significantly (negatively) related to multiple negative mood scale scores (anxiety-tension, depression-dejection, anger-hostility), total mood disturbance scores, scores on the "anger" and "aggression" subscales of the Group Environment Scale and scores on the "work pressure" subscale of the Work Environment Scale. Taken together, these findings of the effects of leader support align well with observations described above regarding the importance of the "quality", as opposed to the quantity, of social support, as well as with evidence from the broader resilience literature indicating leader support to positively affect subordinate resilience (e.g., Bartone, 2006; Werner & Smith, 1992).

Despite the evidence described above, a multi-year space mission carried out by a crew constrained to a small capsule will most certainly lead to elevated levels of social monotony. However, findings from a study involving four pairs of participants completing a 42-day isolated bed rest simulation provides some interesting evidence regarding social nature and implicit support crewmembers may seek from one another, even in instances of social monotony (Weiss & Moser, 1998). Specifically, a high level of social withdrawal was observed among pairs, yet these individuals often took part in the same activities at the same time. Researchers interpreted

these behavioral habits as being positive strategies for adapting to the boredom and monotony of the bed rest environment, suggesting individuals had an underlying need to at least be alone together.

Coping strategies. In addition to evidence regarding the effects of social support, a considerable amount of evidence in the ICE literature has focused on the effects of various coping strategies as potential protective factors. Evidence gathered from Arctic expedition teams suggests effective coping to be associated with positive adaptation to ICE-based adversity. For example, among three couples completing a year-long High Arctic expedition, Leon, Atlis, Ones, and Magor (2002) found effective coping strategies (problem-focused, positive "self-talk", humor, writing in diaries or communicating with family and friends via email) were those most frequently used, while less effective strategies (e.g., confrontive coping) were reportedly used infrequently. A study of a three-person crew who completed a North Pole expedition found a range of effective coping strategies to have been used by crewmembers, for example: talking over task-related concerns, looking at the situation in a positive way, keeping the goal in sight and thinking about something pleasant (Leon, List, & Magor, 2004). However, no single coping strategy was used with great frequency across all crewmembers, suggesting individual differences in coping strategy preferences. A similar range of coping strategies was used among a two-man North Pole expedition team, with both reporting in post-expedition interviews that reevaluating the situation in a positive way was the coping strategy used to deal with the most substantial adversities they experienced on the expedition (Leon, Sandal, Fink, & Ciofani, 2011). Evidence of the use of effective coping has also been observed in research studying the psychosocial effects of wintering-over at Antarctic stations. For example, women who wintered-over in a largely male group indicated positive reevaluation and problem-focused coping to be

effective, and reported perceived group and individual adaptation at levels similar to that of male winterers (Rosnet, Jurion, Cazes, & Bachelard, 2004).

Evidence from other analogue settings has directly demonstrated the relationships between specific coping strategies and outcomes indicative of resilience. For example, crewmembers taking part in a 105-day space simulation who used disengagement coping were much more likely to report greater depressive symptoms (r = .84) than those who used task-oriented coping (r = .23). In addition, the reported use of mature (e.g., problem solving) and intermediate defense mechanisms (e.g., prosocial behavior) was negatively, albeit weakly, related to depressive symptom scores (r = -.06 and r = -.20, respectively), while the reported use of immature defense mechanisms (e.g., withdrawal) was positively related to depressive symptom scores (r = .14; Nicolas, Sandal, Weiss, & Yusupova, 2013). The effects of multiple coping strategies have also been shown to be significantly associated with reported stress upon the beginning of submarine missions (Sandal, Endresen, Værnes, & Ursin, 2003). The authors found social support-seeking was positively related to reported stress due to social factors, while palliative (e.g., diversion via substance use) and avoidant coping were positively related to reported stress due to homesickness. When measured upon completion of submarine missions, evidence showed that those who used active problem solving coping strategies throughout the missions reported significantly less stress due to homesickness.

The research reviewed above regarding the use and effects of coping strategies among individuals in ICE environments generally aligns with the broader literature. However, evidence regarding coping in ICE environments has also run somewhat counter to what has come to be expected within the broader resilience literature. For example, a review of polar expedition evidence suggests that emotional sharing, as a strategy for coping, is reported infrequently (Leon,

1991). As may be expected, Leon, McNally, and Ben-Porath (1989) found effective coping strategies (e.g., planful problem solving) to be reported prior an expedition, as well as increases in planful problem solving, self-controlling and positive reappraisal during the expedition. However, the researchers also observed increases during the expedition in scores on confrontive coping, distancing, and escape-avoidance strategies; although scores on these coping strategies did remain lower than scores on more appropriate strategies. In a study of an Italian Antarctic summering crew, significant reductions were found in the use of various coping strategies, such as social support-seeking and problem-focusing coping, between pre- and post-mission measurements (Peri, Scarlata, & Barbarito, 2000).

Unexpected effects of specific coping strategies on positive adaptation and psychosocial functioning have also been documented in the ICE literature. For instance, expedition evidence indicates social support-seeking coping to often be ineffective (Leon, 1991). This may be due to the high task-oriented nature of these teams, and such coping behavior may be in response to perceptions of a lack of social support. Among an Israeli submarine crew, Kimhi (2011) found avoidance coping to be an effective strategy, possibly as a means to maintain high cohesion. Most surprisingly, among a crew of Antarctic winterers, a number of coping strategies viewed as healthy and effective in the broader literature were shown to become more strongly (and positively) related to concurrently measured depressive symptoms over time: active cognitive coping (pre: $r = .26$; post: $r = .39$), active behavioral coping (pre: $r = .04$; post: $r = .39$) and information seeking (pre: $r = -.04$; post: $r = .40$; Palinkas & Browner, 1995). Because of the concurrent nature of these relationships, a possible explanation is that the effects of the Antarctic environment may have been too much for wintering personnel, despite attempts to maintain the use of positive and adaptive coping strategies. It is possible that the use of these coping

strategies at least buffered the negative psychosocial effects of the Antarctic station environment, as the researchers found a stronger positive relationship between concurrently measured depressive symptoms and avoidant coping, a relationship that also increased from pre-to-post-mission measurement (pre: r = .40; post: r = .63).

Additional protective factors. Only a limited amount of evidence exists with regard to protective factors beyond social support and coping strategies, yet that which does appear largely aligns with results from the broader literature. For example, self-reported self-confidence scores have been shown to relate negatively to concurrent scores on depressive symptoms (pre: r = -.34; post: r = -.31; Palinkas & Browner, 1995), and self-reported self-esteem and group cohesion scores have also been shown to correlate strongly (Krins, 2009). Krins (2009) also showed self-reported positive affect to be related to individuals' perceptions of stress. Positive thinking and optimism have been identified as characteristics among submariners who successfully adapted to isolation and confinement during submarine missions (Kimhi, 2011). Sense of coherence (e.g., viewing life as manageable and meaningful) and hardiness, together, have been shown to correlate negatively to self-reported anxiety sensitivity (r = -.43) among Japanese Antarctic wintering crews (Weiss, Suedfeld, Steel, & Tananka, 2000). Finally, significantly higher ratings of maturity, emotional control, and adaptability were attributed by supervisors to Antarctic winterers who were both well-liked and viewed as potential leaders than to those who were not. Similar effects were found among comparisons between those viewed as good and bad followers, although well-liked followers were not rated as more adaptable (Nelson, 1964).

Evidence of Growth

Despite the potential adversity and stress that come with ICE environments, the research that exists on growth as a result of these experiences has been fairly consistent. Moreover, the

relationship between protective factors and growth may be cyclical, wherein protective factors contribute to post-adversity growth, which in turn can further enhance protective factors (Tedeschi & Calhoun, 2004). For example, using post-mission semi-structured interviews, Leon et al. (1994) found evidence of post-mission growth among Soviet and American expeditioners. Specifically, many reported increased cultural understanding, self-efficacy, and patience as a result of taking part in the international expedition. Leon et al. (2011) also found evidence of post-mission growth among both members of a two-man team completing a 55-day high Arctic expedition. One reported a strengthened relationship with his significant other after returning, alluding to the possibility that the experience encouraged the two to develop a better understanding of one another. The other reported that the mission made him realize he needed to change his life by increasing his focus on life goals and improving his relationship with his wife. He also reported a sense of disappointment shortly after returning home, indicating that resuming his normal work routine did not allow him the time to make the changes he desired.

With regard to spaceflight, content analysis of autobiographical, memoir, interview, personal diary and oral history data from 97 astronauts suggests the development of both integrity and generativity, post-spaceflight (Suedfeld & Brcic, 2011). Ritsher, Ihle, and Kanas (2005; see also Ihle, Ritsher, & Kanas, 2006) developed a growth and positive change survey, specifically for the context of spaceflight. Preliminary survey results indicate that all astronauts and cosmonauts surveyed reported positive reactions to their experiences in space. Findings also indicate certain positive effects to be widespread among respondents, such as: increased appreciation of Earth's beauty and increased confidence to do more with one's life (Ihle et al., 2006). Researchers also found the positive effects of space were more intense among some

spaceflight veterans than others (Ihle et al., 2006; Ritsher et al., 2005), however data were not available on whether protective factors accounted for observed differences in growth intensity.

Summary

Empirical evidence regarding protective factors' contribution to resilience and growth is relatively scarce within the ICE literature, especially when looking beyond the effects of social support and coping strategies. However, that which does exist seems to align quite well, at least at a basic level, with evidence from the broader resilience and growth literature. This lends support to the potential generalizability of findings from non-ICE to ICE populations. That said, social support-seeking behaviors have been shown to be particularly ineffective in ICE environments, possibly because this strategy may be seen as a sign of weakness. Some ICE evidence also suggests avoidant coping strategies may actually be effective in shorter-term ICE contexts, but may prove detrimental if relied upon heavily throughout long-duration missions. Findings also highlight the fact that abundant protective resources do not guarantee freedom from the potentially negative effects of ICE stressors. Finally, despite the possible hardships associated with ICE environments, and specifically long-duration spaceflight missions, evidence also suggests that these experiences, especially those of spaceflight, often create some form of positive change in individuals.

Enhancing Resilience and Growth in ICE Settings

Thus far, this review has described the conceptual underpinnings of resilience and growth and evidence regarding protective factor effects both within the broader literature and specifically within ICE environments. For the remainder of this review we turn the focus toward ways to enhance resilience and growth potential at the individual and collective levels, as well as toward issues and considerations relevant to efforts to enhance resilience and growth potential in

ICE environments. There are various initiatives by which organizations can enhance the resilience and growth potential of their personnel. This can be done through implementing selection procedures that emphasize relevant protective factors. Resilience and growth can also be enhanced through training and countermeasure procedures.

Selection

The first wave of resilience research focused on identifying factors that differentiated those who successfully adapted to adversity from those who did not (see Table 1), and these factors likely have strong practical utility in selecting individuals most likely to succeed in occupations associated with high levels of risk, such as those involving long-duration space missions. Given the abundance of high-quality astronaut candidates, in terms of various abilities and technical proficiencies, psychosocial protective factors inherent to resilience and growth may prove especially useful for differentiating those best-suited for long-duration missions from the rest of the candidate pool. A recent study indicates resilience dimensions (emotional, family, social, and spiritual) to be strongly related to emotional stability (Vanhove, Herian, Harms, & Lester, 2013), a personality dimension identified as important to performance in ICE environments (Palinkas, Keeton, Shea, & Leveton, 2011). Study results also showed resilience factor scores to contribute substantial variance, beyond that of Big Five personality factors, in predicting job satisfaction (29%), individual and organization-focused organizational citizenship behavior (OCB; i.e., extra-role performance indicators; 5% and 15%, respectively) and intentions to quit one's job (25%). Finally, relative weights analyses (see Kraha, Turner, Nimon, Zientek, & Henson, 2012) assessing the unique contribution of demographics, Big Five personality and resilience scores indicated social resilience dimension scores most strongly predicted job satisfaction, individual and organization-focused OCB, and intentions to quit (51%, 33%, 48%,

and 51% of the variance accounted for, respectively). Taken together, these findings provide evidence of the covariation of resilience dimensions and personality characteristics currently considered relevant to astronaut performance, but also demonstrate the potential incremental validity of resilience-targeted measures in predicting performance and other work-related outcomes.

In addition to selecting individual candidates using measures of protective factors, consideration of crew-level characteristics during mission selection will likely contribute to crew resilience. For example, poor crew compatibility may have been partly to blame for events during the SFINCSS-99 simulation, which likely created additional and unnecessary strain on crewmembers (Baranov et al., 2001). Evidence has demonstrated the weakening effects adversity can have on protective factor resources (e.g., Holahan, Moos, Holahan, & Cronkite, 1999; Kaniasty & Norris, 1993), and minimizing sources of adversity wherever possible in ICE environments will increase the likelihood that protective factors will successfully contribute to positive adaptation to other sources of adversity. The composition of crew-level characteristics is one area where mission leaders have an opportunity to minimize potential sources of adversity. Given that interpersonal issues have been consistently identified as substantial sources of stress during spaceflight and analogue ICE missions (Davis et al., 2008, Morphew, 2001; Geuna, Brunelli, & Perino, 1996), optimizing crew compatibility may substantially reduce the impact that adversity has on crewmember functioning. Crew-level selection procedures may involve evaluating candidates with regard to similarity in or complementary personality characteristics (e.g., Bishop, 2004) or values (e.g., Sandal, Bye, & van de Vijver, 2011). Related, evidence also exists regarding “fit” in ICE settings. That is, person-organization fit has been shown to significantly relate to winterers’ ratings of job satisfaction and group cohesion (Sarris & Kirby,

2005), a finding that may be extended to person-team fit as a means of providing greater depth in evaluating crew-level characteristics during selection for long-duration missions.

Training and Countermeasures

The third wave of resilience research has been defined by the study of the effectiveness of interventions intended to promote protective factors (e.g., Masten, 2007). These interventions have been implemented among a wide range of at-risk populations, including: maltreated children (Fantuzzo et al., 1996), low-income urban minority children (Reynolds, 1998), children in war-torn countries (Tol et al., 2008; Tol et al., 2012); young adults transitioning to college life (Seligman, Schulman, DeRubeis, & Hollon, 1999), adults receiving treatment for breast cancer (Antoni et al., 2001) and traumatic brain injury (Bédard et al., 2003); hospital personnel (Sood, Prasad, Schroeder, & Varkey, 2011); and soldiers preparing for deployment (e.g., Van Breda, 1999), on combat deployment (Lunasco, Goodwin, Ozanian, & Loflin, 2010) and returning from combat deployment (e.g., Adler et al., 2009; Prevail Health Solutions, 2011). Resilience-building interventions have also been implemented universally as a means of primary prevention in schools (e.g., Barrett, Lock, & Farell, 2005) and military (Harms, Herian, Krasikova, Vanhove, & Lester, 2013) and non-military organizations (Gardner, Rose, Mason, Tyler, & Cushway, 2005; Luthans, Avey, Avolio, & Peterson, 2010; Luthans, Avey, & Patera, 2008; see also Luthans, Vogelgesang, & Lester, 2006).

Resilience-building interventions have also been evaluated with regard to a wide range of negative and positive outcomes. Notable negative outcomes include anxiety, depression and PTSD, and the effect of interventions on these outcomes has been evidenced among a range of the target populations described above. For example, resilience-building interventions have been associated with reduced anxiety among: at-risk (Berger, Pat-Horenczyk, & Gelkopf, 2007) and

general student populations (Barrett, Sonderegger, & Xenos, 2003), employees recently returned from stress-related absenteeism (Grime, 2004) and service members affected by the 9/11 attack on the Pentagon (Litz, Engel, Bryant, & Papa, 2007). In addition, such interventions have been associated with reduced depression among: children of alcoholic parents (Roosa et al., 1989), adolescents as part of a school-based universal program (e.g., Kowalenko et al., 2005; Pattison & Lynd-Stevenson, 2001), and service members returning from deployment who experienced high combat exposure (Adler et al., 2009) and potential trauma (Litz et al., 2007). Finally, resilience-building interventions have resulted in reduced PTSD and trauma symptoms among: students (Barrett et al., 2003), children living in war zones and regions experiencing political violence (Berger et al., 2007; Jordans et al., 2010; Tol et al., 2008), and at-risk service members (Castro, Adler, McGurk, & Bliese, 2012; Litz et al., 2007).

Resilience-building interventions have also been associated with positive outcomes among a similar range of target populations. For example, resilience-building interventions have been successfully used to increase self-esteem/efficacy among: elementary students (Barrett et al., 2003), minority and urban adolescents (Cardemil, Reivich, & Seligman, 2002; Cowen, Wyman, Work, & Iker, 1995), first-year college students (Franklin & Doran, 2009), tsunami survivors (Gelkopf, Ryan, Cotton, & Berger, 2008), and military medical staff (Hammermeister, Pickering, & Ohlson, 2009). They have been shown to increase feelings of hope among: children living in conflict-affected countries (Jordans et al., 2010; Tol et al., 2008) and adults within the U.S. (Cheavens et al., 2006). They have also been shown to increase benefit finding (i.e., growth) and optimism among breast cancer patients (Antoni et al., 2001); posttraumatic growth among college students prone to stress (Dolbier, Jaggars, & Steinhardt, 2010); job satisfaction and purpose in life among government employees (Waite & Richardson, 2004);

psychological capital and performance among employees and managers (Luthans et al., 2008; Luthans et al., 2010); and cohesion among pre-deployment military personnel (Sharpley, Fear, Greenberg, Jones, & Wessely, 2008).

Taken together, these findings suggest that training aimed at developing protective factors can have robust effects across various populations and on a range of outcomes. Given the risk factors facing individuals who take part in long-duration spaceflight missions, efforts to enhance protective factors that contribute to positive adaptation and psychosocial functioning in these environments may have considerable effects on individuals' capacity for resilience and growth, as well as individuals' performance and overall mission success.

Resilience-building interventions in the military. While distinct from ICE missions, military service involves a similarly unique set of stressors with which one must deal. From demanding physical activities, to long stretches of inactivity in garrison, to potential combat experience when deployed, service members experience a range of stressors. Military agencies and researchers have spent considerable effort identifying the types of stressors experienced by military service members, as well as their psychological reactions to them. As this research has matured in recent decades, resilience has emerged as a construct of importance. Recent reviews of the military resilience literature illustrate the centrality of the construct in this particular setting by demonstrating the vast number of ways in which the study of resilience has been applied in military settings (Wald et al., 2006) and by cataloging the range of methods used by military entities to develop and enhance psychological resilience (Meredith et al., 2011).

There have been a number of preventive efforts in military contexts, especially among deployed soldiers. Some of these interventions have been conducted during the pre-deployment phase. For example, stress debriefing has been conducted among U.S. soldiers regarding ways to

effectively deal with particular stressors likely to be experienced during deployment (Sharpley et al., 2008). However, results indicate only a small overall positive effect for this intervention on soldiers' psychosocial functioning when measured 18 months post-intervention. Another program known as the Operational Stress Training Package (Deahl et al., 2000) was implemented among British soldiers and consisted of a half day of training related to relaxation techniques. The results showed no major impacts upon post-traumatic stress disorder (PTSD), though no baseline data were recorded prior to the implementation of the program. The lack of strong evidence for the pre-deployment resilience-building interventions described above is not necessarily due to the inability of pre-deployment interventions to be effective. Instead, the weak results are possibly due to the debriefing method used, which has come under scrutiny as an effective strategy for prevention and treatment (see Deahl, Srinivasan, Jones, Neblett, & Jolly, 2001).

Other pre-deployment interventions focused on developing resilience-based protective factors have been more effective (e.g., Van Breda, 1999). In addition, protective factor-building interventions have also been shown to be effective when implemented post-deployment, both as a means of aiding soldiers in managing stress and trauma experienced during combat deployment and improving their ability to transition back to civilian life. One such program is BATTLEMIND, which focused on a variety of skills, including: understanding the influence of thoughts and feelings on behavior, avoiding thinking traps, identifying and challenging underlying maladaptive beliefs, putting problems into perspective, and learning to maintain calm and focus under stress (e.g., Adler et al., 2009).

There have also been a number of resilience-building programs implemented in military settings that have not revolved around combat deployment, but instead around other potentially

stressful aspects of military life. For example, various resilience-building programs have been implemented in the context of basic training, as means of helping recruits adapt to military life. These include interventions conducted among Australian Army recruits (Cohn & Pakenham, 2008) and U.S. Air Force recruits (Cigrang, Todd, & Carbone, 2000). However, possibly the most successful of which has been the U.S. Navy's BOOTSTRAP program, which focuses on coping, belongingness, thought distortion and stress management skills. The effects of BOOTSTRAP have been shown with regard to a number of psychosocial and performance outcomes (Williams et al., 2004, 2007).

Perhaps the most visible effort of the U.S. military to enhance resilience is currently being undertaken by the Comprehensive Soldier and Family Fitness (CSF2) program. First implemented by the U.S. Army in 2010, the program uses a combination of assessment, online training modules, face-to-face training, and secondary training to promote resilience among soldiers. The online components of the program consist of the Global Assessment Tool (GAT), which is an online survey designed to assess psychological fitness along four dimensions: emotional, family, social, spiritual. Upon completion of the survey, soldiers receive feedback on their scores and are given information about how their scores compare to demographically-similar soldiers. Soldiers are also encouraged to review self-guided resilience-building training modules delivered by computer at soldiers' leisure. The centerpiece of CSF2, however, is the Master Resilience Trainer (MRT) program. The MRT program involves the selection of non-commissioned officers (NCOs) who are assigned to receive 80 hours of resilience training at the University of Pennsylvania. MRT Training is based loosely on the Penn Resiliency Program, a resilience training program that has been long used among adolescents in school settings (see Brunwasser, Gilham, & Kim, 2009 for a review). The training exercises draw on the cognitive-

behavioral framework to teach NCOs the importance of psychological resilience, to emphasize the use of effective coping strategies, and communicate the importance of family and social support networks in bolstering resilience. A train-the-trainer model is used to distribute the program on a broad scale. Thus, NCOs also receive training on how to deliver resilience training to others; upon completion of the course, they return to their units to pass the training on to peers and subordinates.

The effectiveness of CSF2 has been assessed in a number of ways. Researchers have evaluated the impact of MRT training by comparing the GAT scores of soldiers with MRTs in their unit to soldiers without MRTs in their unit. The results showed that soldiers with MRTs in their unit had higher levels of adaptability, more effective coping strategies, were more optimistic, perceived stronger friendships, and were less likely to catastrophize when negative events occurred (see Lester, Harms, Herian, Krasikova, & Beal, 2011). Longitudinal analyses demonstrated that soldiers with MRT trainers in their units also improved over time on optimism and reduced the use of catastrophic thinking at a greater rate than soldiers without MRTs in their unit. Because the GAT relies upon self-reported indicators of fitness, evaluators also sought to assess the impact of the training on the more concrete outcomes of diagnoses for anxiety/depression/PTSD and diagnoses for alcohol/substance abuse problems. The results showed that soldiers with MRT trainers at the unit level exhibited significantly lower rates of alcohol/substance abuse problems than soldiers without MRT trainers at the unit level, but were not significantly different on diagnoses for anxiety/depression/PTSD. Follow up analyses indicated that the reduction in diagnoses was partially mediated by increases in effective coping strategies (Harms et al., 2013).

CSF2 represents a large scale effort to deliver resilience training to an entire population of individuals, and there are a number of lessons that can be taken from the work done by CSF2 for use by NASA's Behavioral Health and Performance (BHP) working group. First, a train-the-trainer approach might be effective in a long-duration mission. Fully teaching in-depth resilience-building skills to one or two individuals—who then pass along the training to others on the mission—might prove to be a more effective approach than delivering less comprehensive training to the entire crew. Second, while we currently know little about the impact of CSF2's computer-based resilience-building modules on psychological health, evidence from other domains suggest that online training programs can enhance resilience (Rose et al., 2013). Therefore, BHP and NASA may seek to explore the potential role of online resilience training—and perhaps resilience training that is somehow related to developments in artificial intelligence—to further the number of avenues through which resilience training can be delivered.

Overcoming mental health stigma. High levels of stigma towards mental health issues exist in military cultures. This often creates a barrier for service members to seek out help when they begin to notice psychosocial symptoms. Although this same level of stigma may not be present in ICE settings, evidence from the ICE literature has demonstrated the negative effects of coping behaviors that involve seeking social support, with reports suggesting that the use of this coping strategy is often not well-received by fellow crewmembers (see Leon, 1991 for a review of Antarctic expedition evidence), potentially because such behavior is seen as a sign of weakness. Within the military context, efforts have been made to provide resilience-building interventions that minimize mental health stigma (e.g., Lunasco et al., 2010), as well as factors that contribute to individuals' reluctance to seek care by providing self-guided resources online

(e.g., Fravell, Nasser, & Cornum, 2011; Prevail Health Solutions, 2011). In the spaceflight context, self-guided online resources, which minimize reluctance to care, may have considerable utility. That is, these countermeasures may be effectively utilized by individuals to identify symptoms, early on, identify the sources of such symptoms, and develop strategies for effective adaptation.

Mission control and family support. Thus far, we have focused largely on training and countermeasures targeting crewmembers. However, countermeasures and training provided to those who play central support roles in crewmembers' lives also have a substantial impact on crewmember resilience and growth. For example, mission control will undoubtedly play a crucial role in the resilience of crewmembers during long-duration spaceflight missions, and scholars have suggested that no group has a greater influence on crewmembers during the flight phase than mission controllers (Brady, 2005). From a psychosocial standpoint, evidence from the ICE literature has shown crewmembers to displace tension and dysphoria on mission control personnel during spaceflight, and control personnel to, in turn, displace tension and dysphoria on management (Kanas et al., 2001c). Displacement of tension from crew to mission control has also been demonstrated in simulation analogues, wherein evidence was also found for decreased crew-mission control relations (Bergan, Sandal, Warncke, Ursin, & Værnes, 1993). This indicates the presence of potentially avoidable stress being placed on both crewmembers and mission controllers, which if minimized allows both groups greater protective resources to utilize elsewhere. Calls have previously been made within the ICE literature to provide psychosocial training to mission controllers (e.g., Brady, 2005; Gushin, Kolinitchenko, Efimov, & Davies, 1996). Given the evidence described above, such training may have substantial utility when

aimed at minimizing excess stress on crews and providing mission controllers effective strategies for supporting crewmembers during spaceflight.

In addition to the importance of mission control, crewmembers' families warrant consideration in the discussion of training and countermeasures that promote crewmember resilience and growth. For example, qualitative analyses by Johnson (2010) indicate social support from family and friends to be important to crewmembers' psychosocial health during spaceflight. Current methods of inflight communication with loved ones back on Earth, such as real time audio and video interaction may be unrealistic during long-duration missions due to expected communication delays. In the context of long-duration spaceflight, social support from family and friends will likely need to be achieved inflight through electronic communication that are time lagged or recorded. Recorded messages can be sent to and from the spacecraft's computer system and viewed or listened to in their entirety upon download. Some resilience training programs have supplemented primary training with a component involving a family member (e.g., Barrett et al., 2003; Reynolds, 1998). These programs aim to develop family members' understanding of the sources of adversity faced by their loved one, as well as provide skills for supporting their loved one's development and maintenance of protective factors. Programs that include a family component have been some of the most effective within the broader resilience literature.

Mission controllers and crewmembers' families can play important roles in the resilience and growth of crewmembers. However, resilience and growth are likely also important among these individuals. For example, spouses of crew members are often left with far greater responsibility at home, while also being expected to provide the social support needed by their spouses who are on the mission. Emphasis on family members' positive adaptation and

functioning via resilience-building efforts implemented within military settings has increased, and empirical evidence has demonstrated resilience-building training to be effective at preparing service members and their spouses for a variety of demands associated with military deployment (e.g., Van Breda, 1999).

Crewmembers' return from long-duration spaceflight will likely also present considerable stress in adapting back to normal life, both for the individual and his/her family. Within the military literature, it has become clear that adaptation is not only important for soldiers during the early stage of deployment, but also upon reintegration, post-deployment. Research has demonstrated many soldiers find it difficult to shed their combat mentality (e.g., Castro et al., 2012). Transitioning from long-term capsule living back to normal conditions is also likely to present a substantial transition, and research has documented such post-mission problems among ICE explorer crews (e.g., Leon et al., 2011). Thus, post-mission monitoring and training aimed at supporting successful reintegration will be important to enhancing crewmembers' resilience during the post-mission transition phase. Moreover, Leon and Scheib (2007) found that, although spouses of ICE expeditioners found adjusting to the absence of their spouse was initially difficult, spouses found it similarly difficult to readjust to previous routines once their spouses returned, with reports of considerable spousal relation issues. Thus, extending post-mission training to couples may improve individual readjustment, as well as help each better understand the issues faced by the other during this period.

Summary

Evidence suggests that resilience and growth can be enhanced through a variety of selection, training and countermeasure procedures. First, selection procedures that involve measures of protective factors and consider crew-level psychosocial compatibility can be utilized

to enhance the collective resilience and growth potential of long-duration spaceflight crews. Second, training intended to enhance protective factors has been shown to be effective among a range of at-risk populations and with regard to various psychosocial and behavioral outcomes. These findings may be expected to generalize to ICE, and specifically long-duration spaceflight, contexts. In addition, a number of characteristics have been discussed which may contribute to greater training effectiveness among crewmembers, including: minimizing stigma and providing supplemental training and countermeasures to mission controllers and crewmembers' families, as a means of supporting primary training techniques provided to crewmembers. Finally, evidence from the ICE and broader literature suggests that resilience and growth training and countermeasures can have positive effects not only for crewmembers, but also close others who are affected by long-duration missions.

Literature Review Conclusions

The present review of theory and evidence offers preliminary conclusions regarding resilience and growth in ICE environments and a foundation for recommendations for enhancing resilience and growth through selection, training and countermeasure procedures:

- A comprehensive set of protective factors has been identified in the broader literature that differentiates those more likely to effectively adapt to adversity and experience post-adversity growth. Evidence has also shown that many of these protective factors can be developed by individuals.
- A number of basic conceptual issues remain in the broader literature with regard to resilience and growth, including: whether these concepts represent processes or outcomes, what magnitude of adversity is necessary for adaptive responses to signify resilience (or positive development to signify post-adversity growth), and what

constitutes positive adaptation (i.e., “bouncing back” vs. maintaining functioning). Nonetheless, resilience (and growth) in the ICE literature is best reflected in psychosocial and behavioral outcomes to which protective factors contribute, despite the presence of adversity (e.g., isolation and confinement) experienced in ICE environments.

- A relative dearth of empirical evidence regarding the effects of protective factors exists within the ICE literature beyond that of social support and coping strategies. However, that which does exist is largely in line with evidence accrued within the broader resilience literature. This may support the generalizability of findings from the broader literature regarding the effect of protective factors on positive adaptation and psychosocial functioning within ICE environments.
- Additional evidence regarding the effects of protective factors in ICE environments runs counter to what has come to be expected within the broader literature. For example, avoidant coping has been shown to be a potentially viable approach to maintaining psychosocial functioning in relatively short-duration ICE missions. However, further evidence may be needed to assess the extent to which this finding can be replicated, and it remains unclear whether this effect is sustainable during longer-duration missions. In addition, social support-seeking behavior has been shown to be negatively related to resilience, which may be due to the high task-orientation of ICE missions or due to stigma towards this type of behavior in ICE settings.
- Protective factors may prove useful in both differentiating otherwise highly and similarly qualified candidates for long-duration ICE missions, as well as improve the collective resilience and potential for growth among ICE crews.

- Consideration of similarity and compatibility among crewmembers on psychosocial characteristics (e.g., personality and values) may reduce sources of adversity among crews during long-duration missions and lead to greater levels of resilience and growth.
- Resilience-building training programs and countermeasures have been shown to be effective among a wide range of non-ICE, at-risk populations, suggesting that these programs may also be effective among various types of ICE personnel. However, a number of characteristics have been demonstrated to influence program effectiveness, including: minimizing barriers resulting from mental health stigma and supplementing primary training programs with mission control and/or family support training. Resilience and growth are relevant not only to crewmembers, but also mission controllers and family members who must adapt to unique stressors associated with long-duration spaceflight missions.

Part II: Operational Assessment

Part II of this report describes the results of semi-structured interviews conducted with subject matter experts (SMEs) on the topic of resilience and growth in the context of long-duration spaceflight. These interview results are considered in relation to the conclusions of Part I of this report and provide a foundation for studying resilience in growth in ICE settings moving forward.

Method

Participants and Procedures

Participants. Interviewees included 10 SMEs who either had direct experience in spaceflight/ICE analogues or experience working with individuals taking part in such missions. This included: three current and former NASA astronauts who completed spaceflight missions,

two NASA psychologists, one NASA flight surgeon, one NASA flight director, one NASA flight instructor, one Antarctic scientist, and one individual who has completed a long-duration Arctic expedition. This diverse sample provided an eclectic set of perspectives on resilience in the context of long-duration spaceflight and ICE settings.

Interview questions. Potential interview questions were initially developed independently by each member of the research team. These questions were then combined into a single question set, with duplicate questions removed. Two of the team members then collaborated to revise existing questions, identify those most essential to the goals of the study, and create additional questions to fill in remaining content gaps. This resulted in the creation of 20 semi-structured interview questions that were used as part of this study. These questions were categorized under four themes: *defining resilience* (seven questions; e.g., "in your mind what does it mean to be resilient?"), *supporting individuals' resilience* (six questions; e.g., "what can mission control do to enhance resilience before, during, and after the mission?"), *supporting team resilience* (four questions; "how do individuals most effectively contribute to team resilience?"), and *developing resilience* (three questions; e.g., "which aspects of resilience are most important to be developed, and why?"). The list of questions is presented in Appendix A.

Interview structure. SME participation and interview sessions were arranged by BHP and conducted via teleconference under the supervision of BHP personnel. Interview sessions were scheduled for one hour each. SMEs were briefed by BHP personnel as to the purpose of the interviews prior to interview sessions. Each session began with the researchers reminding SMEs of this purpose—to collect interviewees' thoughts and opinions regarding resilience in the context of long-duration spaceflight—and informing them that their thoughts and perspectives would provide important insight into these issues.

During each interview three individuals from the research team were present. As a data security and confidentiality measure, the research team agreed not to record interviews. Thus, one research team member led the interviews and two additional members took written notes on SME responses. At the risk of misquoting SMEs, we do not use direct quotes from the interviews. Instead, the interview results presented as part of this report provide a summary of SME responses. Interview results are intended to serve three related purposes: to compare and contrast with existing resilience theory from the broader literature, to provide an experiential-based foundation for future resilience research within the context of long-duration spaceflight, and to inform future efforts to implement resilience-based selection, training, and/or countermeasure initiatives.

Results and Discussion

Defining Resilience

An important first step in the process of developing effective practical solutions is to establish a valid conceptual framework from which to work. Thus, we sought to do just that with regard to resilience in the context of long-duration spaceflight. To begin, we elicited SMEs' own perspective on what it means to be resilient within ICE environments, and prospectively in the context of long-duration spaceflight. Moreover, we sought to identify both threats to resilience, as well as contributing factors.

Definition of resilience. Much as within the broader literature (see Zautra et al., 2010), SMEs definitions of resilience fell within one of two general categories: "sustained functioning" or "bouncing back" (i.e., recovery). In addition, SMEs who defined resilience through sustainment typically focused on the continuously rigorous characteristics of isolation and confinement, while those who defined resilience as bouncing back typically focused on acute

and/or traumatic potential stressors associated with the context. Although debate continues within the broader literature as to which definition best reflects the construct of resilience within specific contexts (e.g., Bonanno, 2004), one NASA psychologist highlighted the importance of both in the context of long-duration spaceflight. That is, he suggested resilience to represent sustained wellness and health within a continually stressful environment, while also maintaining a store of energy that can be called upon in order to bounce back from acute stressors. Related, the flight surgeon suggested that focus shifts across mission phases. In the initial mission phase, resilience is demonstrated through adaption to the space environment. In the interim phase, resilience is demonstrated through maintaining functioning. In the final phase, resilience is demonstrated through successfully preparing for and transitioning back to normal life.

A number of additional definitional insights arose from SMEs' conceptualizations of resilience. First, one NASA psychologist hypothesized resilience to incorporate psychological, physiological, and genetic components, while the Arctic expeditioner explicitly described resilience as a capacity that can be developed. These appear to be two competing definitions, as genetic and physiological attributes are largely not malleable. However, these two definitions can be interpreted as focusing on different aspects of the same model. The psychologist's focus appears to be on the broader set of antecedents. Evidence-based theory from the broader literature does support the idea that resilience is a function of genetic, epigenetic, neurological, psychosocial, and environmental factors (e.g., O'Dougherty Wright et al., 2013; Wu et al., 2013). The expeditioner's focus appears to be on the subset of psychosocial factors (see Tables 1 and 2). The broader literature also suggests that many of these factors can be improved through biofeedback and cognitive-behavioral training (e.g., Brunwasser et al., 2009; Rose et al., 2013).

Thus, these two definitions are actually complimentary, with one focused on the broad foundation of elements, and the other specifically targeting those malleable elements.

Second, most SMEs took an individual-level perspective when explicitly defining resilience—that is, they described "the individual's" response and adaptation to stress and adversity. This is the approach taken in the majority of resilience research in the broader literature. However, the isolation and confinement aspects of ICE environments differ greatly from the day-to-day living environments within which resilience is often studied. Given these unique characteristics, a common theme throughout the interviews was the centrality of interpersonal and team aspects of resilience among those sharing the confined environment (i.e., the crew). The flight instructor made this aspect explicit in defining resilience, describing it as a "team's" ability to anticipate, monitor, and adapt to problems, as well as learn from those experiences. Thus, the first major departure in defining resilience in ICE contexts, in comparison to typical environments, is the tremendous importance of the crew, as a whole (i.e., collective resilience).

In summary, resilience in the long-duration spaceflight context can be defined as the process by which individuals and the team continually rely on a range of static and modifiable biopsychosocial and environmental resources to sustain effective functioning despite the everyday rigors associated with spaceflight (e.g., ambient noise, isolation), while maintaining a cache of resources for effectively bouncing back from acute stressors (e.g., equipment malfunction, loss of contact with mission control, interpersonal conflict).

Threats to resilience. In the above section, SMEs described two basic types of adversity: continuous and acute. SMEs were also asked to describe the greatest threats to resilience crewmembers will likely face during long-duration missions. Responses varied

greatly, but can be categorized as follows: environmental/technical, physical/physiological, and psychosocial. This wide range of threats to resilience associated with long-duration spaceflight is consistent with previous research (Geuna et al., 1996). SMEs identified potential communication lags, confinement/capsule size (and lack of privacy), radiation, temperature (either too cold or too warm for long periods), and a lack of trained expertise regarding the ship's hardware, software, and operations as major environmental/technical sources of adversity. In addition, one former astronaut highlighted the fact that in-orbit crews have a spectacular view of Earth, but that there will be nothing to see during much of the Earth-to-Mars transit period. SMEs indicated major physical/physiological threats to include: general discomfort, sleep deprivation, fatigue, and physical exhaustion, along with additional physiological responses to the space environment (e.g., vascular restriction). With regard to psychosocial factors, social isolation, boredom and a loss of focus or efficiency were frequently identified.

Social factors were commonly cited as threats to resilience. Nearly every SME indicated crew incompatibility as an important potential source of interpersonal conflict during missions, especially those long in duration. For example, the flight director pointed out that crew incompatibility is less of a threat during current International Space Station (ISS) missions, because the station is large enough that individuals can retreat to physical space away from the rest of the team. SMEs identified both personality and attitudes as important compatibility factors. An additional important aspect of life on the ISS is that real time contact with family and friends on Earth is always possible. However, in the context of long-duration missions, where real time contact will often not be possible, crew incompatibility will create greater problems as crewmembers rely on each other more and more for social support. Notably, many of the comments regarding social indicators of resilience were not solicited by the interviewers;

instead, SMEs mentioned social aspects of resilience on their own and were able to offer specific examples from their work in which compatibility or incompatibility among team members impacted their (or the crew's) ability to demonstrate resilience and perform efficiently.

Resilience protective factors. It is unlikely that any one protective factor contributing to resilience will effectively minimize all of these potential threats or have optimal protective effects at all points throughout long-duration missions. Nonetheless, we asked SMEs to identify the protective factors they perceive to be most important to crewmembers' ability to demonstrate resilience during long-duration missions. There was considerable overlap between those identified by SMEs and those evidenced within the broader literature. Moreover, the protective factors identified by SMEs align well with the biopsychosocial and environmental components included within the working definition of resilience presented above.

SME-identified protective factors are presented in Table 2. As shown in Table 2 the greatest variety of protective factors mentioned were among those categorized as psychological. The majority of protective factors were identified by multiple SMEs. A positive social temperament (social) was the factor most often identified, being cited by five of the 10 SMEs. Physical fitness and meaningful work were the only physical/physiological and environmental factors, respectively, cited by multiple SMEs as important to resilience. The most commonly cited psychological factors were: the ability to manage emotions, the ability to compartmentalize, a sense of humor, and being motivated to carry out the mission. SMEs often justified the importance of the ability to mentally compartmentalize—that is, to be fully conscious of and focus on the issue at hand—because many distractions can arise outside of the mission and outside of the crewmember's control. With regard to humor, one NASA psychologist noted that suppressing frustrations and focusing on getting through the mission may be effective in shorter-

duration missions, but not long-duration missions. Instead, the ability to vent frustrations in a humorous way may be a more effective way of coping with the continual stressors of long-duration missions (e.g., boredom, monotony). Finally, a former astronaut described how an almost obsessive motivation to successfully accomplish the mission can prepare individuals for and help them overcome adversity along the way. There was also considerable overlap in the social factors identified by SMEs, further supporting their increased importance in ICE contexts. For example, SMEs cited trust and confidence in fellow crewmembers and willingness to help one another as important social factors that increase individuals' ability to positively adapt to stress and adversity. Moreover, SMEs indicated that individuals' flexibility in adjusting to others' personality as a vital factor in healthy relationships and avoiding unnecessary stress.

Interestingly, one psychologist suggested certain factors to have greater importance at different stages of the mission. For example, he suggested psychological factors such as self-esteem, internal locus of control, and the ability to manage emotions as fundamental characteristics needed prior to a mission. Subsequently, the focus shifts once the mission begins to the social factors impacting day-to-day crew functioning.

Supporting Individual Resilience among Crewmembers

Within the broader literature social support has been identified as crucial to individuals' ability to demonstrate resilience. The importance of social factors within long-duration ICE contexts is also clear from the interview results presented above. Thus, we sought to elicit perspectives on what different groups who have the greatest impact on crewmembers' psychosocial health could do to support crewmember resilience. Based on existing programs used in the military context (Cacioppo, Reis, & Zautra, 2011; Casey, 2011; Gottman, Gottman,

& Atkins, 2011) we identified four potentially important sources of support: peers (fellow crewmembers and mission control), crewmembers' families, and the sponsoring organization.

Table 2. *SME-identified Resilience-based Protective Factors*

Protective Factors		# of times mentioned
Environmental		
	meaningful work	2
	normalized environment (e.g., access to news, video from family-related events)	1
	recreational activities (e.g., virtual reality, opportunity to earn degree)	1
Physical/Physiological		
	physical fitness	3
	physiological reactions	1
Psychological		
	ability to manage emotions	4
	agreeableness	1
	cognitive ability	1
	compartmentalization/ability to focus on tasks	3
	curiosity/openness to different experiences and perspectives	2
	effective planning and problem-solving	2
	emotional stability/positive mindset	2
	internal locus of control	2
	introversion	1
	low need for power	1
	motivation	3
	self-efficacy	2
	sense of humor	3
	stress tolerance/ability to stay calm	2
Social		
	altruism	3
	comradery (e.g., trust and confidence in other crewmembers)	3
	effective leadership	1
	social skills/ability to listen and interact appropriately	4
	social temperament/ability to adjust to others' personalities/collegiality	5
	supportive network (e.g., family)	1

Other crewmembers. A number of the social factors presented in Table 2 were reiterated with regard to what individuals can do to support the resilience of other crewmembers. The expeditioner suggested crewmembers can support the resilience of others by setting aside personal feelings and acknowledging the effort and performance of team members. The flight controller suggested that the most resilient crews he worked with were those who went out of their way to work together and help one another out. This point was echoed by the expeditioner through two specific examples—when, unprompted, a team member finished his laundry while posted at an Arctic station, and when another surprised him with a snack while the two were taking a break during a grueling Arctic patrol. These anecdotes capture the ideas of both altruism and comradery and highlight how demonstrating effort with regard to "the small things" can have a positive effect on the well-being of crewmembers.

Mission control. A number of insights were provided regarding what mission control can do to support crewmember resilience. The main recurring theme was that mission control and crews need to make an effort to get to know one another on a personal level prior to the mission. As the flight controller stated, this will facilitate free and open communication between the two groups during the mission. A former astronaut highlighted the importance of candid communication. He described an instance when he unknowingly made a mistake while carrying out a task under the direction of mission control and his frustration over the fact that mission control noticed the mistake but was unwilling to directly inform him of it. Related, multiple SMEs indicated the importance of basic behaviors on the part of mission control, such as acting in a trustworthy fashion, providing valid and honest information in a time-sensitive manner, acknowledging crewmembers' effort and performance, being sympathetic to the experience of crewmembers, and providing crewmembers encouragement. For example, a former astronaut

described the importance of mission control understanding that even basic tasks are more difficult to carry out in zero gravity, and they need to show patience when working with crews. SMEs also cited aspects of mutual crew-mission control relations as being important. For example, one NASA psychologist indicated the importance of regular communication between the crew and mission control regarding the expectations of one another, while the other NASA psychologist cited the importance of neither mission control personnel nor crewmembers being oversensitive in their interactions. Finally, one of the NASA psychologists also emphasized that mission controllers must care for themselves and each other—that is, be cognizant of sleep deprivation or other personal issues—as he mentioned that crews are very perceptive of issues on the ground.

Family. Although not directly involved with the task-related aspects of missions, family was unanimously cited as having an integral role in supporting and maintaining the resilience of crewmembers. Specifically, SMEs either implicitly or explicitly indicated the importance of crewmembers having the full support of families. For example, one former astronaut described how crewmembers become more focused on the mission and less focused on family life as the launch date approaches. During the pre-mission phase, he described, crewmembers are able to focus their emotional resources when families understand and are accepting of this. Pre-mission, a former astronaut indicated it was also helpful for him and his spouse to be explicit about responsibilities and expectations while separated. In fact, an issue that surfaced throughout these interviews was the importance of defining expectations—for example, between individual crewmembers, the crew and mission control—and this was indicated as being a crucial aspect of effective family support. Specifically, the expeditioner indicated expectations regarding the amount and timing of communication should be discussed.

There were also a number of ways family can support crewmember resilience during the mission. One way cited by the flight surgeon was to send family news updates and even video of children's games, plays, etc. During the mission, one NASA psychologist indicated that one of the best ways for families to support the resilience of crewmembers was to manage themselves so not to place additional and potentially avoidable stress on individual crewmembers and the crew, as a whole. The same NASA psychologist mentioned that over-dependence among crewmembers on the support of their families is also problematic.

Finally, multiple SMEs emphasized the importance of families during the post-mission phase. Upon returning from a long-duration mission, crewmembers will be readapting to, among other things, gravity, open spaces, and increased environmental stimulation, in general. The flight surgeon likened this process to that of soldiers returning from combat and suggested that crewmembers will be quite reliant on their families during the first month or two post-mission, as they work to readapt to normal life. One former astronaut made a similar point. He described when he returned from a space mission he was able to rest and unwind with only his immediate family for two weeks in Russia, prior to returning to the United States. He indicated that having this time, before being overwhelmed by extended family, friends, and the community back home, was very helpful to his readjustment.

The organization. SMEs described recommendations regarding the structure, procedures, and available resources surrounding a long-duration spaceflight mission in order to maximize resilience. There were two overarching themes that repeatedly arose among these recommendations. Stated simply, one issue cited by a number of SMEs was that greater emphasis needs be placed on selecting the right people for long-duration missions. With regard to this, recommendations followed two more specific paths. First, it was recommended that

greater attention be placed on resilience protective factors (see Table 2), in addition to the current emphasis on technical skills. Second, it was recommended that greater emphasis be placed on evaluating potential crewmembers' compatibility with one another. Recommendations were made with regard to multiple characteristics, including psychological (e.g., personality) and behavioral (e.g., individual sleep cycles) aspects of compatibility.

The other major theme of recommendations that arose through interviews regarded developing relationships prior to missions. The first relational recommendation emphasized inter-crew relations. Related to the recommendation of increasing attention to crew compatibility, a former astronaut, a NASA psychologist, and the flight surgeon all cited the importance of crews training together and being given time get to know each other prior to any long-duration mission. This will allow crewmembers to familiarize themselves with and adjust to the personalities of the other crewmembers. A former astronaut said he could not stress enough how having ample time to feel each other out, socialize, and train together helps the crew support each other during stressful situations. The second relational recommendation emphasized crew-mission control relations. With regard to this, one former astronaut made a fairly basic yet profound observation during the interview by stating that during space missions, whether short or long in duration, it helps to actually know the person whose voice is on the other end of the intercom. One NASA psychologist indicated that increased interpersonal communication between the flight director and the crew can help foster resilience among crewmembers. The flight controller stated that mission controllers used to go on training missions with crews (e.g., kayaking or backpacking trips), which created bonding experiences and tighter mission control-crew relationships. Bringing these back, he said, may be valuable for long-duration missions. As other SMEs described the importance of crewmembers getting to

know each other's personalities, the psychologist suggested that increased familiarity among the crew and mission control personnel prior to a long-duration mission can serve to build rapport between the two groups. Mission controllers' ability to build rapport with a crew prior to the mission will likely be vital to their ability to be perceived by the crew as honest and trustworthy, which has the potential to increase the resilience of crewmembers.

There were a number of other points raised. One made by multiple astronauts, the flight controller, and the flight surgeon was that crewmembers need to be better included in mission planning and task execution. For example, the flight controller suggested that crewmembers want to be included in mission planning beforehand and decisions during the mission. Similarly, the flight surgeon cited the heavy downtime crewmembers will have during the transit phase and suggested that crewmembers should have increased say in deciding how to spend that time. Related, a former astronaut suggested that crewmembers will need to be provided greater autonomy. Currently, crews' days are scheduled down to the minute and mission control is very involved in walking crewmembers through most tasks. He pointed out that this strategy will not work with the communication time lags inherent to a long-duration mission. Instead, crews will need to be able to manage and maintain the spacecraft. The former astronaut suggested that doing so will provide the crew meaningful tasks to help fill transit time, fight off boredom and monotony, and generally keep the crew engaged during the flight. Finally, as alluded to above, mission control's understanding of the difficulty and amount of time it takes to complete tasks in space is important, and a former astronaut suggested (re)instituting the policy that at least one mission controller have spaceflight experience. This individual will be able to provide the perspective of an astronaut in mission control, which may help reduce any negative relations that result from a lack of perspective on the part of mission control.

Aspects of Team Resilience

As suggested by conceptualizations of resilience put forth by SMEs, the importance of the team-based resilience is amplified within the spaceflight context. We sought to elicit SME perceptions regarding the characteristics that, specifically, hinder and contribute to team resilience. These characteristics build on the broad social factors identified in Table 2. While we found greater orthogonality in threats to and protective factors of resilience, we found that team issues associated with resilience more often represent two different ends of a single continuum. For example, the Arctic expeditioner suggested positivity and negativity to be contagious, mentioning that one member has the ability to lift the entire crew up or bring them down.

One factor that was often cited as being crucial as a threat to, and promoter of, resilience was leadership. Specifically, the flight surgeon identified the importance of leader-follower relations and trust. One former astronaut highlighted a specific mission in which the commander was initially perceived as insecure and controlling. Subsequently, the astronaut's response to an acutely stressful event during the mission served to build trust between the astronaut and his commander and strengthen relationships within the team. SMEs also suggested that the leader's role in long-duration missions may be different from that in shorter missions. Two SMEs (a NASA psychologist and the Arctic expeditioner) hypothesized that the crew structure used in long-duration missions will likely be flatter than it currently is in short-duration missions, or at least will become so over the course of the mission. In this model, crew leadership will likely be egalitarian, and the official commander will likely only take on the leadership role in the case of emergencies. However, the flight instructor suggested that having the right commander—one with strong technical and interpersonal skills—impacts crew functioning and resilience during

shorter-duration spaceflights. Thus, even if only in emergency situations, a leader who can take charge and instill confidence in the crew will likely be vital to crew resilience.

Crew compatibility continued to be emphasized in discussing team resilience with interviewees. For example, a former astronaut noted that it is not usually the "oddball" who causes problems in the group. Instead, it is usually the crewmember who cannot tolerate the "oddball." This also highlights the importance of social temperament or the ability to adjust to others as resilience protective factors (Table 2), as well as the recommendation to increase attention to crew compatibility prior to any long-duration mission. Related, the flight surgeon cited that it also is not necessarily the quiet person in the group that leads to issues; these individuals, he described, tend to provide thoughtful and helpful ideas. Instead, those who create threats to crew resilience are those who are standoffish.

At a basic level, the Antarctic scientist described a crew as analogous to a military unit or a sports team, wherein each crewmember needs to be mentally and physically prepared for the mission and to understand what might be expected of him or her. A number of SME responses also reflected this idea. In particular, the flight controller and Artic expeditioner described the importance of a shared understanding of and continued focus on team goals, to which each crewmember agrees with and supports. The absence of this can have severe consequences through reduced team functioning and increased stress and conflict. The flight controller and expeditioner also highlighted the need to establish how each person fits into the team and to make sure each member is clear about and comfortable with his or her responsibilities. Related, both the flight instructor and one of the NASA psychologists described the importance of clarifying individual expectations and responsibilities prior to the mission, and the need to periodically revisit these issues throughout the mission. In essence, these subsequent

recommendations serve to maintain efforts for achieving the shared goals described by the Arctic expeditioner. Also in line with the sports team/military unit analogy, the flight controller cited the importance of "everyone having everyone else's back" and crewmembers pitching in the help one another when necessary. Related, the flight instructor indicated coordination and collaboration among the crew and a shared situational awareness to be important to crew resilience.

SMEs also described the importance of more basic inter-crew relations. For example, a former astronaut who took part in a mission with a predominantly Russian crew cited the importance of socialization outside of work-related tasks (e.g., eating meals together, occasionally having movie nights). Conversely, the astronaut also stressed the importance of the need for privacy as being an acceptable social norm, suggesting a need to have respect for the emotional and physical boundaries of every member of the team. At a broader level, the astronaut described these issues as reflecting a need for mutual respect among crewmembers. One NASA psychologist observed that individual crewmembers' openness to teamwork and training contribute to crew-level resilience. More broadly, a former astronaut and the Antarctic scientist suggested that a collective openness to and excitement over experiencing exploration and general curiosity as important to team resilience.

As in any social situation, disagreement and interpersonal conflicts are sure to arise throughout the mission, and many of the SMEs stressed the importance of open communication among the group, and more specifically talking out problems when they do arise. Drawing on experiences in long-duration analogue missions, the Arctic expeditioner and the Antarctic scientist both emphasized it is important that crewmembers do not ignore problems, as doing so can lead to more significant conflicts later on.

Finally, two SMEs (the flight instructor and the flight director) described team resilience in the spaceflight context as extending beyond the spaceflight crew to include mission control. This perspective fits quite well with many of the operational factors cited above as contributing to team-level resilience (e.g., shared goals, defining and maintaining expectations, cooperation/coordination, and openness in communication). In addition, this reinforces the importance of mission control as a central source of crewmember support and recommendations of creating greater familiarity between mission control and crews, preflight.

Developing Resilience through Training

In the final set of interview questions we sought to elicit SME perspectives on how to most effectively enhance crewmember resilience through training procedures. Many points raised by SMEs in response to earlier interview questions were revisited in this portion of the interviews. Further, SMEs identified many practical barriers that exist, and offered a diverse set of observations and practical recommendations regarding paths to address to these issues.

The flight instructor noted that current technical training educates crews on how to handle emergencies, which has important implications for crewmember resilience. However, one former astronaut explicitly mentioned that the effects of such training remains limited. That is, he described how even when problems can be anticipated (speaking of training for emergency or high stress situations) one never really knows how he or she will react until actually experiencing such a scenario. A number of points related to this issue were raised by SMEs. First, the flight director pointed out that it is difficult to simulate the high-stress conditions crewmembers may experience in space among “well-fed and well-rested” crews on the ground during the preflight phase. Second, a former astronaut suggested that long simulations may not be necessary to identify how individuals will handle long-duration confinement. Instead, he

suggested that shorter missions where trainees are provided limited resources are likely more effective at eliciting responses to stress that will likely arise during long-duration missions. Third, the Antarctic scientist highlighted the importance of training missions having tangible goals. He stated that a mission to Mars or other exploration-class destinations would not simply be to "stick a flag in the ground". Instead, these missions will serve important scientific purposes. He surmised that the motivating factors of these missions differ greatly from those in which the goal is simply to experience ICE environments for a given period of time.

A number of SMEs emphasized the importance of crews training together extensively. Their rationale was that this served the purpose of assessing crew compatibility, and it would allow crewmembers to become familiar with and adjust to other crewmember personalities. That said, a practical barrier identified by the flight instructor is the already substantial amount of preflight technical training crewmembers receive. This, along with the current practice of selecting crews only a short time prior to missions, led the flight instructor to question whether preflight resilience-building procedures among an intact crew are currently possible. As one alternative, he suggested that resilience training may be best situated prior to crew selection. As another alternative, he suggested resilience training may be well-suited for the initial transit period of the mission. The structure of long-duration missions, such as that to Mars, will differ from the highly coordinated structure of current shorter-duration missions, in that the transit phases (>6 months to Mars) will create considerable amounts of downtime for crews. Multiple SMEs acknowledged current concerns over identifying ways to keep these crews busy during these periods. Thus, offering computer-based learning modules that focus on various aspects of resilience may also contribute to filling up downtime during transit. Moreover, resilience

training during this phase may be advantageous in that crewmembers will experience training under some of the actual conditions to which they must be resilient.

A final point related to resilience training targeting crewmembers was raised by the flight surgeon and one NASA psychologist. He stated that efforts need to be made to maintain and enhance resilience throughout the various phases of spaceflight missions, and he cited the post-mission phase as one period currently being given little attention. He went on to suggest that there is little known about how astronauts cope with and readjust to life on Earth, and training is currently not provided for these purposes.

The importance of mission control and crewmember families to crewmember resilience is clear from SME responses throughout these interviews, and one NASA psychologist explicitly recommended that resilience training must extend beyond crewmembers to involve these groups. He suggested that psychosocial health and resilience among families and mission control is also important to mission success. Thus, resilience training targeting these individuals will be imperative. For example, he and the flight surgeon both suggested that crewmembers and their families should receive training in preparation for long-term separation. This point echoes a former astronaut's description of the positive effects pre-mission spousal counseling had on his and his family's ability to successfully adapt to his absence during spaceflight missions.

A number of SMEs (astronaut, flight controller, flight director, flight surgeon, and psychologist) cited the need for team-building among the crew and flight directors. Resilience-based training that involves both crewmembers and mission control personnel may help develop familiarity and trust. In addition, the flight instructor suggested that mission controllers may benefit from efforts to enhance empathy over the experience of long-duration crews in order to avoid creating unnecessary stress. More specifically, the flight controller described how training

was, at one time, provided to mission control personnel educating them on what stressors crews are likely to experience, how they might respond, and why crewmembers might act in certain ways. The flight controller suggested this type of educational training to be valuable to reintroduce for long-duration missions.

With respect to the specific factors that training procedures might entail, those identified as contributing to resilience (Table 2) were reiterated here. Specifically, most SMEs focused on emphasizing social and team-related factors, as can be seen through an emphasis on crew-family and crew-mission control training recommendations. However, one NASA psychologist suggested that both stress inoculation and mindfulness training may be of value in the long-duration context.

Taken together, SME responses highlight a number of important practical considerations, needs, and recommendations. From these responses it is clear that emphasis on developing and maintaining crewmember resilience is needed throughout mission phases (i.e., preflight, inflight, and post-flight). It is also clear that for future efforts to be effective they must involve each of the deeply intertwined units that contribute to crewmember resilience (i.e., the intact crew, mission control, and crewmembers' families). Finally, it is important that future efforts to enhance resilience consider the practical barriers associated with the structure of spaceflight missions (e.g., heavy preflight technical training) and training initiatives be created to optimize training effectiveness, while not overloading crewmembers and other relevant training targets.

Operational Assessment (Part II): Conclusions

Results from the operational assessment (Part II) generally aligned with the conclusions drawn from the literature review (Part I). In addition, these results build on the general conclusions in Part I of this report by offering a number of specific insights on how to support

and enhance resilience within the long-duration spaceflight context. Common themes identified through these interviews include:

- Group and interpersonal aspects of resilience have increased importance in isolated and confined environments. Even basic conceptualizations of resilience involve a strong interpersonal component, with resilient crews being those in which each individual member: understands his or her role and responsibilities, understands and supports crew goals and objectives, has trust and confidence in his or her fellow crewmembers, and is willing to help and support others.
- Mission control plays a vital role in maintaining and enhancing crewmember resilience during the flight phase. Previous literature has suggested mission control to play a central role in crewmember health during spaceflight missions (e.g., Brady, 2005), and the importance of mission control to crewmember resilience was clearly demonstrated in SME responses. SMEs indicated mission controllers can support crewmember resilience, for example, by acting in an honest, trustworthy, and efficient manner, and by understanding and being sympathetic to the experience of stressors associated with spaceflight.
- Family (and close others) also play a crucial role in the resilience of crewmembers throughout pre-to-post-mission phases. There is no "magic bullet" specifically regarding how families can best support crewmembers' resilience. Instead, SMEs suggested the "how" typically comes down to specific family dynamics and expectations. However, demonstrating support (however appropriate), keeping them informed, and not introducing additional and unnecessary stress are general ways to support crewmembers' resilience.

Together, the literature review and SME responses contribute to recommendations for enhancing crew resilience.

Recommendations for enhancing team aspects of resilience include:

- Providing training aimed at maintaining and developing resilience-based protective factors to crewmembers, potentially as interactive, self-administered, computer-based modules that can be completed pre-mission or during the transit phase of a long-duration mission. Computer-based resilience training programs exist, but the validity of these remains somewhat unclear. Sophisticated and interactive training modules need to be developed and evaluated in analogue ICE settings.
- Placing greater emphasis on crew compatibility. Specifically, selection procedures should consider the potential compatibility of crewmembers. Importantly, we do not suggest compatibility analyses to be carried out strictly on the basis of individual similarity. Instead, we suggest identifying characteristics detrimental to crew compatibility. For example, it may be beneficial to identify individuals who cannot tolerate potential personality and character quirks in others, and eliminate these individuals from consideration.
- Providing ample opportunity for crews to familiarize themselves with and adjust to one another prior to long-duration ICE missions. This was one of the most cited themes in SME responses regarding ways to enhance resilience. SMEs offered multiple recommendations, and NASA will need to determine the most effective and efficient ways of achieving this goal. NASA will have to determine how much time is necessary for teams to establish sufficient familiarity. Also, NASA will need to determine which

avenues (e.g., formal training, informal team-building, or both) are most effective at promoting familiarity.

Recommendations regarding mission control include:

- Increasing familiarity between crewmembers and members of mission control. Much like recommendations to increase familiarity among crewmembers, developing greater familiarity and more personal relationships between crewmembers and mission controllers should enhance mutual respect, open communication, and trust. Again, NASA will need to determine the most effective and efficient ways of achieving this goal, including the amount of time needed to sufficiently foster familiarity and the avenues through which to promote familiarity.
- Providing psychoeducational training to mission control so that mission controllers better understand obstacles and stressors the crew will be subjected to during a long-duration mission, identify negative effects of stress and stress-related symptoms among crewmembers, and efficiently communicate with crewmembers when either or both sides are experiencing elevated levels of stress.
- Maintaining and enhancing psychological health and resilience among mission controllers will likely enhance crewmember resilience, or at least minimize threats to crewmember resilience associated with mission control relations. Therefore, it would be beneficial to develop countermeasures and training for use among mission controllers. It is understood that psychoeducational training focused on the above issues is currently being developed for mission controllers. This training should be consistent with the training to be given to crews and should undergo rigorous evaluation prior to deployment

to determine effects on mission controller and crew perceived stress and communication effectiveness.

Recommendations regarding crewmembers' families include:

- Providing family and spousal training prior to long-duration missions to establish expectations for familial communication and support and prepare the crewmember and his/her family for the changing responsibilities during the long-duration mission. This training should be consistent with training given to crew and mission control.
- Providing family members support throughout the long-duration mission and psychoeducational training to prepare them to support crewmembers' readjustment to normal living, post-mission.

Recommendations for crewmembers, mission control and families include:

- Providing consistency in themes and common language across countermeasure, training, and other resilience-based efforts implemented among crews, mission control, and families in order to maximize the effectiveness of any specific effort.

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Appendix A

Resilience Questions

Introductions: [Interviewee first]…– we have been conducting research on resilience and healthy psychosocial functioning with other agencies and are beginning to apply that experience and knowledge to the context of spaceflight

How one's resilience can positively affect his or her broader psychological health and performance has received a lot of attention within various contexts, such as that in response to military combat.

Yet, it hasn't been established what it means to be resilient and how resilience manifests itself specifically in the context of space missions.

As someone who closely interacts with astronauts, we are going to ask you a series of questions in order to get insight on these issues, and your answers to these questions will help guide our research.

Just to let you know, some of your responses may be quoted within the body of our report to NASA, but this will be completely anonymous.

Demonstrating Resilience

1. In your mind, what does it mean to be resilient? For example, what characteristics does a "resilient" astronaut possess?
    a. Drill down whatever characteristics mentioned.
        i. Why in this context?
        ii. How is it demonstrated?
2. What coping strategies are most effective?
3. What are the biggest threats to the resilience of astronauts?
    a. What are the most stressful aspects of missions?
4. Please give a specific example from your current job where you have had to demonstrate resilience.
    a. IF NON-ASTRONAUT PERSONNEL ASK ABOUT HIS/HER OBSERVATIONS OF ASTRONAUTS
    b. Please give a specific example where you have observed an astronaut demonstrate resilience.

Understand Social Factors

1. What things can other people do to enhance resilience/well-being before, during, and after the mission?
    a. Ground control?
    b. Family?
    c. Other crewmembers?

Understand Environmental Factors

(Moving now to the organization)

2. What can NASA do to enhance resilience?
    a. Policies and procedures?
    b. Resources?

3. What, if any, programs offered by NASA have been most valuable in teaching astronauts to be resilient?

Team-Related Aspects of Resilience

1. A common saying is that the "whole" is greater than the sum of its individual parts. In the context of resilience, can you think of any crew- or group-level characteristics or processes associated with team resilience?
    a. In other words, what does a resilient team look like?
2. How do individuals most effectively contribute to group resilience?
3. How much does the resilience of one member impact the rest of the team?
    a. In other words, do you think that resilience (or non-resilience) is contagious?
4. How do you minimize the negative effects of one team member's lack of resilience?

Developing Resilience

1. In your opinion, do you think resilience can be trained?
    a. No: Why?
    b. Yes: Which aspects of resilience are most important to be developed, and why?
    c. What is the best way to deliver training?
        i. For example, do you think a classroom approach would be best? Or is it something that should be individualized through online training?

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13. ABSTRACT *(Maximum 200 words)*
This report is designed to increase understanding of resilience and growth in isolated, confined, and extreme (ICE) environments. Part I of the report begins with a review of the broader academic literature on resilience and growth. This literature has identified various individual, social, and environmental factors that protect individuals and teams from the negative effects of stress. Although there is only limited empirical evidence concerning the effects of these protective factors in ICE environments, it largely aligns with the effects observed within the broader literature. Specifically, perceived social support, problem-focused coping strategies, and positive cognitive reappraisal of stressors serve as important factors contributing to resilience and growth in ICE environments. Part II of this report describes the results of interviews with 10 subject matter experts (SMEs) regarding the conceptualization and the role of resilience and growth in long-duration space missions. Major themes identified by SMEs include: a) the social aspects of resilience are more salient due to the nature of ICE environments, b) crew compatibility has substantial effects on individual and crew resilience, and c) external entities (e.g., family, mission control, the organization) play an important role in both contributing to and threatening resilience and growth among astronauts.

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