

Health of U.S. Navy Submarine Crew During Periods of Isolation

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Background: An essential element in planning for long-term space missions is prediction of the medical support required. Medical data for analogous populations serving in isolated and/or contained environments are useful in predicting health risks for astronauts. **Methods:** This study evaluated the rates of health events that occurred among a highly screened, healthy military population during periods of isolation using a centralized database of medical encounter records from U.S. Navy submarines. The study population was composed of U.S. Navy officers and enlisted men deployed on 240 submarine patrols between 1 January 1997 and 30 September 2000. **Results:** A total of 1389 officers and 11,952 enlisted crew members served aboard participating submarines for 215,086 and 1,955,521 person-days at sea, respectively, during the study period. Officers had 214 initial visits to medical staff with 79 re-visits for the same condition during these patrols, while enlisted men had 3345 initial visits and 1549 re-visits. Among officers, the most common category of medical events was respiratory illnesses (primarily upper respiratory infections), followed by injury, musculoskeletal conditions, infectious diseases, symptoms and ill-defined conditions, and skin problems. Among enlisted men, the most common category of medical events was injury, followed by respiratory illnesses (upper respiratory infections), skin problems, symptoms and ill-defined conditions, digestive disorders, infectious conditions, sensory organ problems (ear infections and eye problems), and musculoskeletal conditions. **Conclusions:** Potential mission-impacting medical events reported were rare, i.e., among a crew of seven officers, only one medical event would be expected to occur during a 6-mo mission and result in 3/4 d or less of limited or no duty. Among a crew of seven enlisted men, about two medical events would be expected during a 6-mo mission and result in about 1 d of limited or no duty per medical event.

Keywords: submarine, health, epidemiology, surveillance, isolated environment.

PREDICTING THE TYPES of medical events that might occur during and following prolonged excursions in space is difficult due to the small numbers of astronauts who have traveled for lengthy periods; however, several studies have examined post-flight morbidity and mortality (5,6,8). In a survey of clinical and research professionals involved in NASA medical programs regarding their perceptions of the medical risk of spaceflight, respondents indicated that skin disorders were likely to be the most common risk in spaceflight but would have little effect on the mission, while the risk of circulatory disease was likely to be the lowest, but could have a significant effect on the mission (1). The authors concluded that the results of the survey, combined with data from analogous populations and

existing astronaut health data would be used to support decisions about health care resources needed for long-term spaceflight (1).

Life aboard a submarine is similar in many ways to that aboard a spacecraft, including isolation, closed environment with artificial atmosphere, working and living in crowded quarters, limited space for medical supplies, non-physician health care providers, pre-mission health screening, and the precedence of the mission over individual needs. However, there are also some important differences between space and submarine environments which would influence the type of health events seen as well as the ability to treat them. These include conditions of microgravity in space, age and educational status of the crew, the ability to communicate outside of the vessel, the size of the crew, and the role of medical care providers.

Submariners are a relatively young, healthy population of males who undergo periodic stringent physical and psychological screening for duty. Ambient air aboard a submarine is continuously monitored and adjusted to control the levels of oxygen, carbon monoxide, carbon dioxide, and environmental contaminants such as hydrocarbons. Medical care onboard is provided by an Independent Duty Corpsman (IDC), a non-physician with specialized medical training. Prolonged isolation during lengthy missions, changes in work-rest schedules, and disturbances in circadian rhythm may influence the health of the crew.

Submarine officers may be a better analog for astronauts than their enlisted counterparts because of their

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older age and higher level of education. However, as the space program develops and larger and more diverse crews are sent, some members may be more like the submarine enlisted men. Thus, it is important to consider both officers and enlisted men as possible analogs for future astronaut populations. A recent report proposed a method for conducting surveillance of the health among deployed submariners (10). At the time of publication, data for only 136 submarine patrols were available for analysis. A subsequent paper based on an expanded series of 196 patrols described in detail the types of accidents and injuries occurring aboard the submarines (11). Data from a total of 240 patrols are now available for analysis, with sufficient numbers of officers and enlisted men to analyze the two groups separately.

METHODS

The primary source of data for this study was the onboard automated medical system, which contains clinical and demographic information on crewmembers serving aboard U.S. Navy submarines. IDCs are required to make an entry for each medical event requiring a prescription medication, a medical procedure, or crewmember assignment to limited or no duty. From 1 January 1997 through 30 September 2000, demographic and medical encounter data from 240 U.S. Navy submarine patrols of 10 d or greater were gathered, processed, and stored in a centralized computer database, which is described in detail elsewhere (10). Up to three diagnostic codes were assigned to each medical event during deployment using general ICD-9 coding guidelines for outpatient encounters (3), with some modifications for the present study due to the unique practice setting. The first recorded ICD-9 code was used as the primary diagnosis for each medical encounter. Events were classified as "illness" or "accident" based on the presence or absence of an accident report; however, some of the events classified as "illness" could be due to injuries for which an accident report was unnecessary.

Incidence density rates for each type of illness occurring during the study period were calculated using the number of encounters (excluding re-visits for the same complaint) as the numerator and the total number of person-days underway as the denominator. The number of person-days for each subject onboard each deployment was calculated using the duration of time the submarine was underway. Numerator data and the corresponding person-days underway were totaled by ICD-9 category and by demographic characteristics of the officers. Rates were expressed by 100 person-years.

RESULTS

All of the submarine crew members were male and over 90% of the officers and 88% of the enlisted men were white (Table I). More than 50% of the officers were age 30 or older and 42% served in the military for 10 or more years, reflecting their senior status among the crew. Among enlisted men, more than 35% were age 30 or older and two-thirds had five or more years of military service. Ninety-five percent of the submarine

TABLE I. DISTRIBUTION OF SUBMARINE OFFICERS AND ENLISTED CREW MEMBERS ABOARD 240 SUBMARINE PATROLS, 1 JANUARY 1997 TO 30 SEPTEMBER 2000, BY DEMOGRAPHIC CHARACTERISTICS.

	Officers		Enlisted	
	Number	Percent	Number	Percent
Ethnic Background				
White	1281	92.2	10,529	88.1
Non-White	79	5.7	1237	10.4
Unknown	29	2.1	186	1.6
Age (Years)				
< 25	48	3.5	4534	37.9
25-29	632	45.5	2944	24.6
30-34	382	27.5	2232	18.7
35+	320	23.0	2200	18.4
Unknown	7	0.5	42	0.4
Length of Military Service (Years)				
< 5	247	17.8	3946	33.0
5-9	465	33.5	2805	23.5
10-14	305	22.0	2254	18.9
15+	272	19.6	2071	17.3
Unknown	100	7.2	876	7.3
Smoking Status on Last Physical Exam				
Smoker	30	2.2	1725	14.4
Non-Smoker	1323	95.3	9883	82.7
Unknown	36	2.6	344	2.9
Total	1389	100.0	11,952	100.0

officers and 83% of the enlisted men were non-smokers. The officers and enlisted men spent 215,086 and 1,955,521 person-days at sea, respectively, during the 240 patrols.

A total of 214 initial visits to the IDC for a medical event and 79 re-visits for the same condition were recorded among officers during the 240 patrols. The overall rate was 36.3 medical events per 100 person-years (Table II). Among enlisted men, 3345 initial visits for a medical event and 973 re-visits for the same condition were recorded during the 240 patrols. The overall rate was 62.5 events per 100 person-years. Smokers had higher rates of illnesses than non-smokers. Among officers, illness rates increased with age and length of military service, while accident rates decreased. Among enlisted men, the rate of illnesses did not vary significantly by age or military service, but the rate of accidents decreased also with both characteristics. Higher educational level was associated with a higher rate of illness among officers; however, the opposite relationship was noted for accidents. The rates of illnesses and accidents were higher on patrols of less than 60 d than among longer patrols.

The potential mission impact of illness and injury appears to be minimal (Table III). The 214 medical events among officers resulted in a total of 156 estimated days of limited or no duty, about 3/4 d per event, or about 26 d per 100 person-years at sea. Among enlisted men, the 3345 medical events resulted in a total of 3602 d of limited or no duty, or about 1 d per condition. Seventy-three percent of the officers and 67% of enlisted men who sought medical care for an illness were able to assume their full duties, and the estimated number of limited or no duty days was greater than 2 for only 4.2% of the officers and 7% of the enlisted men.

TABLE II. RATES OF MEDICAL EVENTS AMONG OFFICERS AND ENLISTED CREW MEMBERS DURING 240 SUBMARINE PATROLS BY TYPE OF EVENT, DEMOGRAPHIC CHARACTERISTICS,* AND DURATION OF PATROL.

	Officers						Enlisted					
	Illness		Accident		Total		Illness		Accident		Total	
	# of Events	Rate/100 Person-Years										
Total	190	32.2	24	4.1	214	36.3	2527	47.2	818	15.3	3345	62.5
Smoking Status on Last Physical Exam												
Smoker	6	55.8	0		6	55.8	430	54.8	129	16.4	559	71.2
Non-Smoker	175	31.1	24	4.3	199	35.4	1983	44.8	662	15.0	2645	59.8
Age (Years)												
< 30	85	27.9	13	4.3	98	32.2	1668	48.8	632	18.5	1300	67.3
30+	105	37.1	11	3.9	116	41.0	854	44.2	183	9.5	1037	53.7
Length of Military Service (Years)												
< 5	37	30.9	7	5.8	44	36.7	928	50.4	410	22.3	1338	72.7
5-9	49	24.7	7	3.5	56	28.3	552	43.6	165	13.0	717	56.6
10-14	45	34.7	7	5.4	52	40.2	468	42.7	119	10.8	587	53.5
15+	53	46.3	2	1.8	55	48.1	434	47.0	81	8.8	515	55.8
Years of Education												
13-16	121	31.2	17	4.4	138	35.6	2129	47.2	704	15.6	2833	62.9
17+	46	38.4	3	2.5	49	40.9	261	42.4	70	11.5	331	54.2
Duration of Submarine Patrol												
< 60 Days	48	47.9	7	7.0	55	54.9	524	61.2	173	20.2	697	81.4
60+ Days	142	29.0	17	3.5	159	32.5	2003	44.5	645	14.3	2648	58.8

*Events stratified by demographic characteristics may not add to the total because subjects with unknown smoking status, age, and length of military service are excluded from the corresponding sections of the table.

Among officers who had accidents, more than 80% were able to assume their full duties, and only 3 of 21 officers required 1 or more days of limited or no duty following an accident. Most lost duty days were due to musculoskeletal conditions (46 d), followed by injury (26 d) and respiratory illnesses (11 d). Among enlisted crew members who had accidents, the potential impact was greater. About 35% were assigned to limited or no duty, and about 22% were assigned to limited duty for more than 2 d. The most common cause of limited or no duty days among enlisted men was injury (1824 d), followed by digestive (403 d), musculoskeletal (350 d),

skin (347 d), symptoms/ill-defined (168 d), and respiratory (163 d) conditions.

Among officers, the highest morbidity rate was for respiratory illnesses, followed by injury, musculoskeletal disorders, infectious conditions, and skin disorders (Table IV). All but one of the respiratory illnesses were upper respiratory infections. The remaining respiratory illness event was reported to be allergic rhinitis. The most common form of injury was open wound, followed by superficial injuries. Sprains and strains accounted for only a small proportion of injuries. The rate of injuries among officers age 30 and older was higher

TABLE III. MEDICAL EVENTS AMONG OFFICERS AND ENLISTED CREW MEMBERS DURING 240 SUBMARINE PATROLS BY DISPOSITION.

Disposition*	Officers						Enlisted					
	Illness		Accident		Total		Illness		Accident		Total	
	#	%	#	%	#	%	#	%	#	%	#	%
Full Duty	139	73.2	20	83.3	159	74.2	1698	67.2	461	56.5	2159	64.5
Limited Duty	11	5.8	2	8.3	13	6.1	208	8.2	216	26.4	424	12.7
No Duty	30	15.8	1	4.2	31	14.5	386	15.3	74	9.0	460	13.8
Other	10	5.3	1	4.2	11	5.1	235	9.3	67	8.2	302	9.0
Estimated Limited/No Duty Days												
None/Not Recorded	149	78.4	21	87.5	170	79.4	1930	76.4	527	64.4	2547	73.4
1-2	33	17.4	1	4.2	34	15.9	414	16.4	110	13.5	524	15.7
3-7	6	3.2	1	4.2	7	3.3	127	5.0	137	16.8	264	7.9
8-14	1	0.5	0	0.0	1	0.5	37	1.5	34	4.2	71	2.1
15+	1	0.5	1	4.2	2	0.9	19	0.8	10	1.2	29	0.9

*Full duty = able to assume all regular duties; limited duty = able to assume some but not all of regular duties; no duty = unable to assume regular duties; other = not recorded or referred for consultation.

TABLE IV. RATES OF MEDICAL EVENTS AMONG OFFICERS AND ENLISTED CREW MEMBERS DURING 240 SUBMARINE PATROLS BY AGE.

Category (ICD-9 Codes)	Officers						Enlisted					
	Total		Age < 30 Years		Age 30+ Years		Total		Age < 30 Years		Age 30+ Years	
	# of Events	Rate/100 Person-Years	# of Events	Rate/100 Person-Years	# of Events	Rate/100 Person-Years	# of Events	Rate/100 Person-Years	# of Events	Rate/100 Person-Years	# of Events	Rate/100 Person-Years
Infectious/Parasitic Diseases (001-139)	19	3.2	8	2.6	11	3.9	187	3.5	145	4.2	42	2.2
Intestinal Infections (008)	12	2.0	4	1.3	8	2.8	99	1.9	78	2.3	21	1.1
Non-Psychotic Mental Disorders (300-316)	0	0.0	0	0.0	0	0.0	101	1.9	70	2.0	30	1.6
Nervous System/Sense Organ Disorders (320-389)	15	2.6	6	2.0	9	3.2	191	3.6	120	3.5	71	3.7
Disorders of Eye & Adnexa (360-379)	6	1.0	3	1.0	3	1.1	54	1.0	40	1.2	14	0.7
Disorders of Ear & Mastoid Process (380-389)	6	1.0	3	1.0	3	1.1	114	2.1	69	2.0	45	2.3
Circulatory System Disorders (390-459)	8	1.4	1	0.3	7	2.5	27	0.5	16	0.5	11	0.6
Respiratory System Disorders (460-519)	56	9.5	30	9.9	26	9.2	515	9.6	353	10.3	160	8.3
Upper Respiratory Infections (460-466, 480-487, 490)	55	9.3	30	9.9	25	8.8	502	9.4	348	10.2	152	7.9
Digestive System Disorders (520-579)	12	2.0	4	1.3	8	2.8	191	3.6	132	3.9	59	3.1
Dental Problems (520-528)	5	0.8	1	0.3	4	1.4	78	1.5	54	1.6	24	1.2
Noninfective Gastroenteritis (558)	3	0.5	2	0.7	1	0.4	27	0.5	22	0.7	5	0.3
Genitourinary System Disorders (580-629)	5	0.8	1	0.3	4	1.4	98	1.8	48	1.4	50	2.6
Epididymitis (604)	4	0.7	1	0.3	3	1.1	45	0.8	28	0.8	17	0.9
Skin & Subcutaneous Tissue Disorders (680-709)	18	3.1	12	3.9	6	2.1	436	8.1	324	9.5	111	5.7
Cellulitis & Other Local Infections (680-686)	9	1.5	7	2.3	2	0.7	204	3.8	142	4.2	62	3.2
Ingrown Toenail (703)	5	0.8	3	1.0	2	0.7	106	2.0	92	2.7	14	0.7
Musculoskeletal System Disorders (710-739)	19	3.2	9	3.0	10	3.5	176	3.3	89	2.6	87	4.5
Arthropathies & Related Disorders (710-719)	4	0.7	2	0.7	2	0.7	60	1.1	30	0.9	30	1.6
Dorsopathies (720-724)	5	0.8	2	0.7	3	1.1	52	1.0	27	0.8	25	1.3
Disorders of Ligaments, Tendons, Muscles, Bursae (725-729)	10	1.7	5	1.6	5	1.8	50	0.9	25	0.7	25	1.3
Signs, Symptoms, and Ill-Defined Conditions (780-799)	16	2.7	9	3.0	7	2.5	217	4.1	138	4.1	79	4.1
Injury (800-999, E800-E899)	33	5.6	15	5.0	18	6.4	1079	20.1	803	23.5	272	14.1
Sprains & Strains (840-848)	3	0.5	1	0.3	2	0.7	173	3.2	117	3.4	56	2.9
Open Wound (870-897)	18	3.1	9	3.0	9	3.2	454	8.5	354	10.4	98	5.1
Superficial Injuries (910-919)	7	1.2	3	1.0	4	1.4	71	1.3	48	1.4	23	1.2
Other	12	2.0	3	1.0	9	3.2	117	2.2	55	1.6	62	3.2
Not Coded	1	—	—	—	—	—	—	—	—	—	—	—

than that for younger officers. Musculoskeletal disorders reported among officers were: arthropathies and related disorders, dorsopathies, and disorders of ligaments, tendons, muscles, and bursae, with the latter category accounting for about half. Over 50% of the infectious diseases were intestinal infections. The remaining infectious diseases were a variety of conditions including strep throat, chicken pox, herpes simplex, dermatophytosis, dermatomycosis, and acariasis. Skin conditions reported among the submarine officers were primarily due to local infections and ingrown toenails and rates among younger officers were much higher

than those for officers over the age of 30 yr. Six of the nervous system disorders recorded were eye problems: keratitis, disorders of the conjunctiva, and inflammation of the eyelids. Six were problems with the ears, primarily otitis media and mastoiditis. The remaining events in this category were migraine headaches. Officers age 30 and older had higher rates of infectious diseases, injuries, and disorders of the nervous, circulatory, and digestive systems than did their younger counterparts. Circulatory conditions included one case of hypertension, one case of cardiac dysrhythmia, one case of transient cerebral ischemia, one case of varicose

veins, and four cases of hemorrhoids, which the ICD9 categorizes under "diseases of veins and lymphatics, and other diseases of circulatory system."

Among enlisted men, the highest morbidity rate was for injuries, followed by conditions of the respiratory system, skin and subcutaneous tissue conditions, symptoms and ill-defined conditions, conditions of the digestive system, and nervous system and sense organ disorders. Enlisted men under the age of 30 had nearly twice the rate of injuries as older crew members. Open wounds accounted for the highest proportion of injuries. Respiratory system disorders did not vary substantially by age, and upper respiratory infections accounted for 97% of these conditions. Minor skin infections and ingrown toenails were the most commonly recorded skin conditions and did not vary substantially by age. The category of symptoms and ill-defined conditions included such complaints as abdominal pain ($n = 30$), headache ($n = 28$), chest pain ($n = 26$), elevated BP without diagnosis of hypertension ($n = 13$), syncope ($n = 13$), rash ($n = 12$), vertigo ($n = 12$), epistaxis ($n = 11$), nausea/vomiting ($n = 10$), and other symptoms. Dental problems and gastroenteritis accounted for more than half of the conditions classified as disorders of the digestive system. Disorders of the nervous system and sense organs were primarily eye problems and ear infections (i.e., otitis media). The rate of non-psychotic mental disorders was relatively low (1.9 per 100 person-years at sea) and included primarily stress and adjustment reactions, special symptoms like sleep disorders and headaches, depression, and other types of neurotic disorders.

DISCUSSION

Submarine and spacecraft environments share certain characteristics, including conditions of isolation, and a closed environment with an artificial atmosphere. Thus, some medical conditions may be relevant to both submariners and the astronaut population, and might include circulatory problems, skin conditions, stress and adjustment reactions, and symptoms such as headache, chest pain, and digestive complaints. Skin conditions could be a particular problem in an artificial atmosphere, because the healing process may be prolonged. In the present study, skin conditions ranked among the top five most common categories of morbidity among both officers and enlisted men; however, the risk was very low, about 3.1 per 100 person-years at sea among officers and 8.1 per 100 person-years among enlisted men. As might have been predicted, the risk of circulatory system disorders was very low, and there were only two cases which might have been considered serious enough to affect a mission. No stress or adjustment reactions were recorded among the submarine officers in this study. Acute respiratory illnesses and infectious conditions, which were among the most commonly reported conditions among submariners, may not be an important medical risk during spaceflight, because astronauts currently spend a minimum of seven days in quarantine prior to the flight. The types of injuries occurring aboard submarines may be different than those occurring in space because of the influence of

TABLE V. COMPARISON OF PERCEPTION OF MEDICAL RISK OF SPACE FLIGHT FOR ASTRONAUTS WITH RANKING OF MEDICAL CATEGORIES FOR SUBMARINE POPULATIONS.

Disease Category*	NASA Perception of Risk Survey (1)	U.S. Navy Submarine Officers, 1997-2000	U.S. Navy Submarine Enlisted Crew, 1997-2000	Polaris Submarine Patrols, 1968-1973 (9)
Mental Disorders	2	9	7	7
Sensory	6	5	5-6	6
Circulatory	9	7	9	
Respiratory	4	1	2	2
Gastrointestinal	8	6	5-6	3
Genitourinary	7	8	8	5
Skin	1	4	3-4	4
Musculoskeletal	5	3	3-4	
Injury/poisoning	3	2	1	1

*Categories differ slightly between studies; numbers in parentheses refer to reference numbers; categories are ranked in descending order, with 1 being the highest probability and 9 being the lowest.

gravity; however, the most common types of injuries among submariners were open wounds, which may not necessarily be related to conditions of gravity.

Illness categories evaluated in the NASA study of perception of medical risk during spaceflight (1) are shown in Table V along with the results from the present study on U.S. Navy submariners, as well as a 1979 report on Polaris submarine patrols (9), excluding infectious conditions. Skin conditions were ranked as possibly the highest risk in the NASA survey, but fourth for submariners. If upper respiratory infections were excluded from the ranking of conditions for submarine officers, respiratory conditions would drop to number eight, making injury the highest ranking category. Mental disorders ranked last among submarine officers, since there were no events, and seventh among enlisted men, while the NASA survey ranked mental disorders as possibly the second highest risk. While the NASA survey ranked circulatory conditions as possibly the lowest risk, this study of U.S. Navy submarine officers indicates that circulatory conditions may not be the lowest risk; however, half of the circulatory conditions (i.e., hemorrhoids) reported among U.S. Navy submarine officers would be likely to have little or no effect on a space mission.

The present study has numerous advantages over early studies of illness rates among submariners and other analog populations (1,2,9,10). The number of subjects in the study was large ($n = 13,441$), as was the number of person-days at risk accumulated during the study period (over 2 million). The present study is the first to evaluate morbidity rates among deployed U.S. Navy submarine officers. Previous studies of submariners have reported morbidity for all submariners irrespective of rank (9,10,11), hospitalization rates (2), or mortality (4,7). The only previous study similar to this one used average crew strength and assumed each patrol was 60 d in length in order to calculate person-days at sea (9). These estimates for calculating the denominators for rates of medical events did not allow analyses by demographic variables. The present study improves on these methods by providing more accurate denom-

inator data. In addition, the study by Tansey et al. (9) included only those events resulting in at least one lost duty day, corresponding to only about 14% of the events evaluated in the present study.

Limitations of the present study include the variation in the quality and completeness of data recorded by the IDCs, the small numbers of events available for analysis in some specific categories of illness and injury, and the lack of women in the population. For most of the participating submarines, the medical notes contained sufficiently detailed information to code diagnoses and procedures. However, some were brief, and codes were assigned based on minimal information. In a very small number of cases, the code selected by the IDC was assumed to be correct because no medical notes were recorded. Although there are general guidelines regarding required entries, some IDCs appeared to be more thorough than others in recording all events meeting these criteria. Our study population consisted of men only, so data on women's health during periods of isolation are still needed. Despite these limitations, this group may be one of the best analogous populations for predicting health risks to astronauts during spaceflight.

In summary, potentially mission-impacting medical events reported among officers aboard submarine patrols were rare (36.3 per 100 person-years underway; i.e., among a crew of seven individuals, one medical event would be expected to occur during a 6-mo mission). The officers are most analogous to current space program participants. Enlisted men, who may also be informative as the space program expands, had 62.5 events per 100 person-years underway; i.e., among a crew of seven individuals, about two medical events would be expected during a 6-mo mission. The majority of the medical events reported among officers and enlisted men could be considered minor and non-life-threatening, with little or no impact on unit mission.

Disclaimer

The opinions expressed in this manuscript are those of the authors and do not necessarily reflect those of the National Aeronautics and Space Administration, the Department of Defense, or the United States Navy.

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Terry Lynn Duel Thomas, a senior staff scientist at the National Cancer Institute, died March 3, 2002 of breast cancer. Dr. Thomas, a career epidemiologist, worked at federal government agencies in the Washington area for the past 31 yr. Her pioneering work on the health of submariners was invaluable not only to the U.S. Submarine Fleet, but also the future of prolonged spaceflight. She served as a member of several national and international groups studying occupational and radiation health issues and since 1995 had been U.S. co-leader of a Working Group of the U.S.-Russian Federation Joint Coordinating Committee for Radiation Effects Research. All those who had an opportunity to work with her will miss her.

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