



Applying a Crew Accommodations Resource Model to Future Space Vehicle Research A CASE STUDY

Jennifer Linda Blume, Ph. D.

NASA-Marshall Space Flight Center

Allied Aerospace Industries, Jacobs Sverdrup MSFC Group

Huntsville Simulation Conference

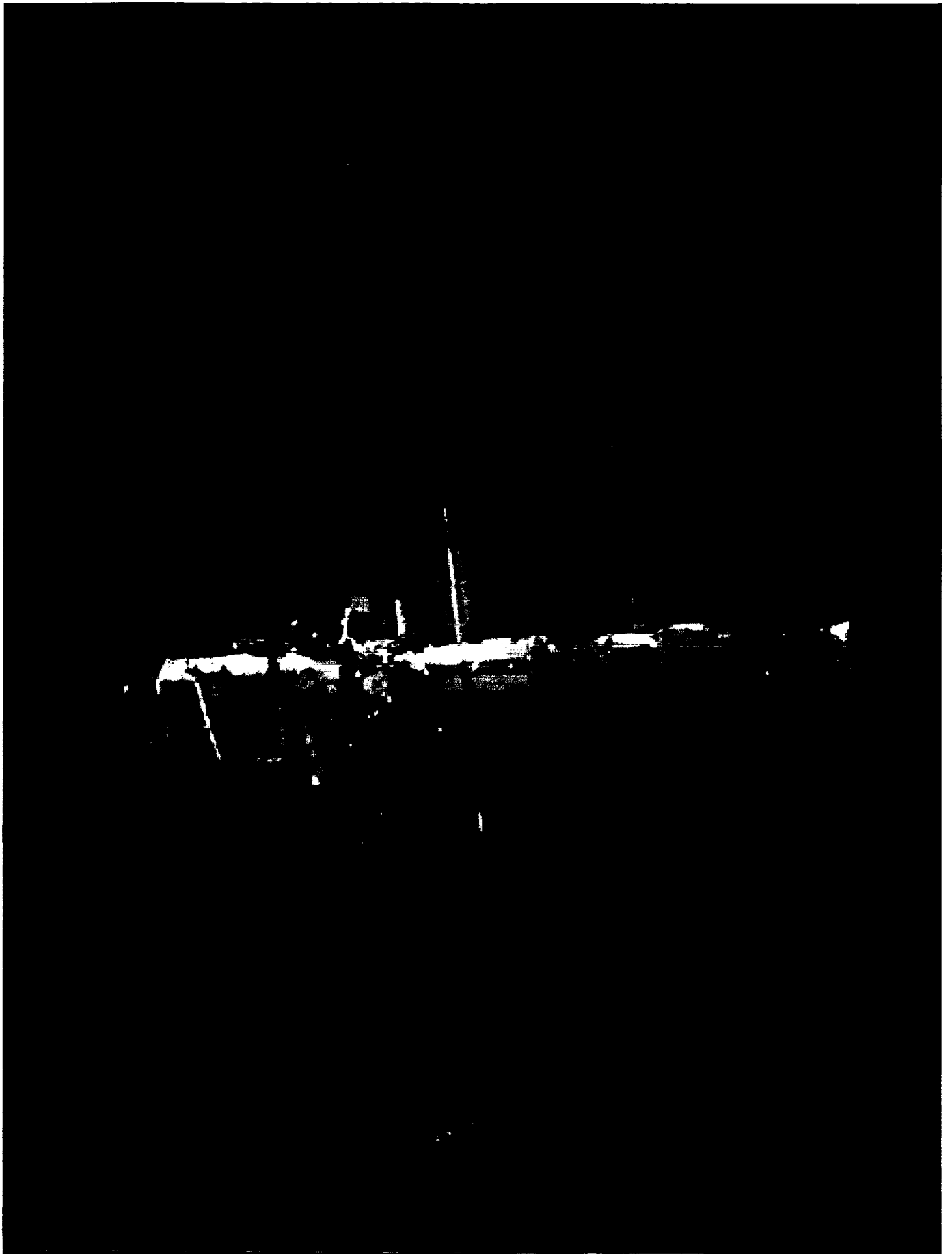
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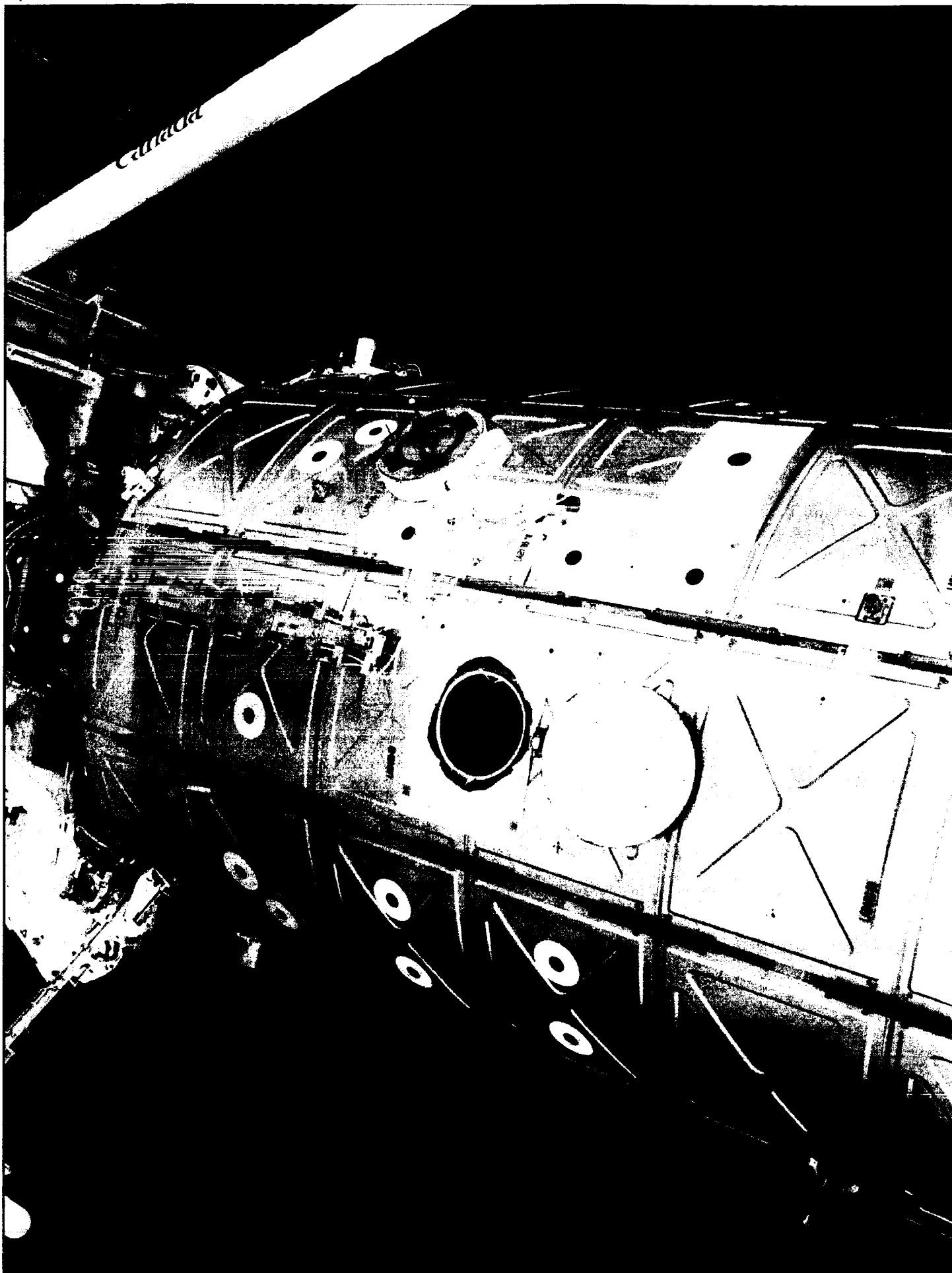


Overview

- Modeling for space vehicle design
 - The Human Factor
 - The Mission Factor
- Test Case of a crew resource model
 - The Problem
 - Crew Accommodations Resource Model*
 - Conclusions on model's utility for working the problem

* Stillwell, D., Boutros, R., & Connolly, J. (1999) "Crew Accommodations". In Larson & Pranke (Eds.) Human Spaceflight Mission Analysis and Design (Space Technology Series), McGraw-Hill, Inc.



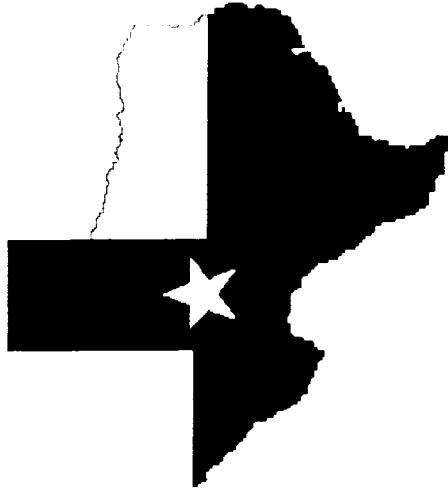






Who am I?

Native Texan recently transplanted
in Huntsville, Alabama



Southwestern University
GEORGETOWN, TEXAS



Human Factors & Applied Cognitive Psychology
Department of Psychology, Texas Tech University
Lubbock Texas

Experimental
Psychologist by
Training



NATIONAL AERONAUTICS
AND SPACE ADMINISTRATION



MARSHALL SPACE
FLIGHT CENTER
HUNTSVILLE, AL

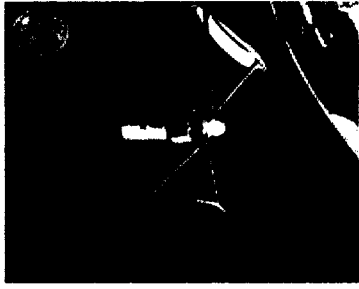
Space Human
Factors Specialist
by Trade



Modeling and Final Design

Many interrelated factors affect space vehicle performance

Conceptual R&D depends heavily on models of such factors



Factors used in the models become design drivers and requirements for actual vehicles



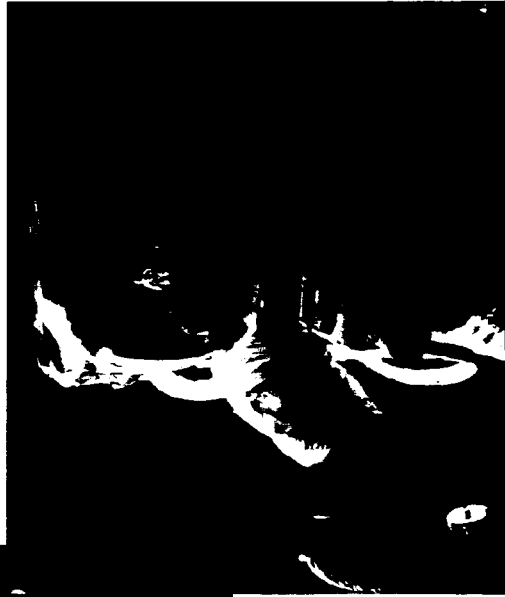
The Human Factor

Adding a human is more than merely multiplying an adequate volume by the quantity of crew...



Humans compound the necessary factors by requiring additional systems and hardware as well as consumables

- Breathable air & system
- Pressure control
- Food and water
- Waste management
- Radiation protection
- Emergency safety equipment
- Medical equipment
- Exercise equipment
- Personal and operational volume
- Supplies
- Control stations
- Artificial gravity





The Mission Factor

Resources required for human presence change as mission duration or purpose change

Quantity or type of supplies
Type of equipment & facilities
Amount of personal space



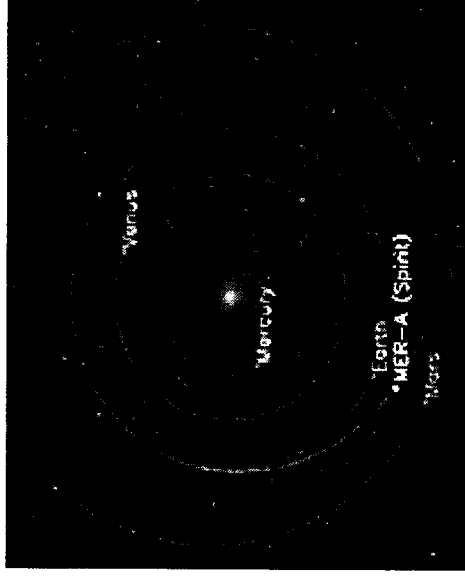


The Test Case

Determine mass and volume for conceptual vehicle

Vehicle will carry crew – determine human impact to mass and volume

Extremely long duration
missions: 750, 1110, 1470 days



➔ *Crew Accommodations Resource Model**

* Stillwell, D., Boutros, R., & Connolly, J. (1999) "Crew Accommodations". In Larson & Pranke (Eds.) Human Spaceflight Mission Analysis and Design (Space Technology Series), McGraw-Hill, Inc.



Crew Accommodations Model

Resource Model published in Chapter 18, "Crew Accommodations", in Human Spaceflight Mission Analysis and Design. Stilwell, D., Boutros, R., and J. Connolly. New York: McGraw Hill Companies, 1999.

"Crew accommodations" defined as those elements of mission supplies, hardware, and software that most directly serve human needs throughout every phase of a mission

- Sleep accommodations and crew quarters
- Galley, food system, and wardrobe
- Housekeeping and waste disposal
- Personal hygiene facilities
- Restraints and mobility aids
- Emergency provisions
- Clothing systems
- Crew health care
- Recreation equipment
- Maintenance equipment
- Photographic equipment



Crew Accommodations Model

The model is a compilation of volume and mass factors for crew accommodations aspects

In addition, it makes assumptions on the calculations based on mission type

- Mars mission is of long duration and must be highly autonomous
- International Space Station mission has some access to Earth for resupply and emergency evacuation
- Shuttle is short in duration

To use the model, input mission duration, mission type, and quantity of crew to obtain mass & volume estimates



Crew Accommodations Model – Mass Factors

Crew Accommodations System	Mass Factors			Assumptions and Notes
	Station-like	Mars hab	Units	
Galley and Food System				
Food	2.3	2.3	kg/p/d	Minimum is 1.8 kg/p/d (current Shuttle allowance)
Freezer(s)		100	kg	Empty freezer (no food mass included)
Conventional ovens	50	50	kg	
Microwave ovens	70	70	kg	Assumes 2 ovens
Cleaning supplies	0.25	0.25	kg/d	Includes solvents and supplies for cleaning galley and ovens
Sink and spigot	15	15	kg	For food rehydration and drinking water
Dishwasher		40	kg	
Cooking/eating supplies	0.5	2	kg/p	
Waste Collection System				
System	45	45	kg	Assumes 1 toilet for each mission except Mars (2 toilets)
Supplies	0.05	0.05	kg/p/d	
Contingency collection mittens/bags	0.23	0.23	kg/p/d	
Personal Hygiene				
Shower	0	75	kg	
Handwash/mouthwash faucet	8	8	kg	
Personal hygiene kit	1.8	1.8	kg/p	
Hygiene supplies	0.075	0.075	kg/p/d	Consumables
Clothing²				
Clothing	69	69	kg/p	Assumes 2.3 kg/p for 1 complete change of clothes
Washing machine	0	100	kg	
Clothes dryer	0	60	kg	
Recreational Equipment				
Personal stowage	10	25	kg/p	



Crew Accommodations Model – Mass Factors

Crew Accommodations System	Mass Factors				Assumptions and Notes
	Shuttle-like	Station-like	Transfer Suite	Mars hab	
Housekeeping					
Vacuum	13	13	13	13	kg Prime and 2 spares
Disposable wipes for housecleaning	0.15	0.30			kg/p/d
Trash compactor/trash lock	0	150	150	150	kg
Trash bags	0.05	0.05	0.05	0.05	kg/p/d
Operational Supplies and Restraints					
Operational supplies	10	20	20	20	kg/p Includes diskettes, ziplocks, tape ...
Restraints	25	83	50	100	kg Assumes all repairs in habitable areas
Maintenance					
Hand tools and accessories	100	200	200	300	kg
Spare parts and consumables					- Assumes no spare parts or consumables for maintenance
Test equipment	50	100	300	500	kg Includes oscilloscopes, gauges, etc.
Other tools and equipment	50	50	600	1000	kg Includes fixtures, large machine tools, gloveboxes, etc.
Photography					
Equipment	120	120	120	120	kg Assumes an all-digital approach
Sleep Accommodations					
Sleep provisions	9.00	9.00	9.00	9.00	kg/p Includes sleep restraints only
Crew Health Care					
Exercise equipment	145	145	145	145	kg Assumes 2 devices for aerobic exercise
Medical/surgical/dental suite	15	250	500	1000	kg
Medical/surgical/dental consumables		125	250	500	kg



Crew Accommodations Model – Volume Factors

Crew Accommodations System	Volume Factors			Assumptions and Notes
	Station-like	Mars hab	Units	
Galley and Food System				
Food	0.0080	0.0080	m ³ /p/d	
Freezer(s)	0	0.50	m ³	
Conventional ovens	0.25	0.25	m ³	
Microwave ovens	0.30	0.30	m ³	Assumes 2 ovens
Cleaning supplies	0.0018	0.0018	m ² /d	Includes solvents and supplies for cleaning galley and ovens
Sink and spigot	0.0135	0.0135	m ³	For food rehydration and drinking water
Dishwasher	0	0.56	m ³	
Cooking/eating supplies	0.0014	0.0056	m ³ /p	
Waste Collection System				
System	2.18	2.15	m ³	Assumes 1 toilet for each mission except Mars (2 toilets)
Supplies	0.0013	0.0013	m ³ /p/d	
Contingency collection mittens/bags	0.0008	0.0008	m ³ /p/d	
Personal Hygiene				
Shower	0	1.41	m ³	
Handwash/mouthwash faucet	0.01	0.01	m ³	
Personal hygiene kit	0.005	0.005	m ³ /p	
Hygiene supplies	0.0015	0.0015	m ³ /p/d	Consumables
Clothing²				
Clothing	0.224	0.224	m ³ /p	Assumes 0.008m ³ /p for 1 complete change of clothes
Washing machine	0	0.75	m ³	
Clothes dryer	0	0.75	m ³	



Crew Accommodations Model – Volume Factors

Crew Accommodations System	Volume Factors				Assumptions and Notes
	Shuttle-like	Station-like	Lunar base	Mars hab	
Recreational Equipment					
Personal stowage	0.19	0.38	0.38	0.75	m ³
Housekeeping					
Vacuum	0.07	0.07	0.07	0.07	m ³
Disposable wipes for housecleaning	0.001	0.002	0	0	m ³ /p/d
Trash compactor/trash lock	0	0.3	0.3	0.3	m ³
Trash bags	0.001	0.001	0.001	0.001	m ³ /p/d
Operational Supplies					
Operational supplies	0.001	0.002	0.002	0.002	m ³ /p
Restraints	0.135	0.54	0.27	0.54	m ³ /kg
Maintenance					
Hand tools and accessories	0.33	0.66	0.66	1.00	m ³
Spare parts and consumables					-
Test equipment	0.15	0.3	0.9	1.50	m ³
Other tools and equipment	0.25	0.25	3.00	5.00	m ³
Photography					
Equipment	0.50	0.50	0.50	0.50	m ³
Sleep Accommodations					
Sleep provisions	0.10	0.10	0.10	0.10	m ³ /p
Crew Health Care					
Exercise equipment	0.19	0.19	0.19	0.19	m ³
Medical/surgical/dental suite	0.25	1.00	2.00	4.00	m ³
Medical/surgical/dental consumables		0.64	1.30	2.50	m ³



Crew Accommodations Model

Mission Type: Mars Habitation | Crew Size: 3 | Duration 750 days

Crew Accommodations System	Mass Factor (see sheet 2)	Mass Subtotal (kg)	Volume Factor (see sheet 3)	Volume Subtotal (m ³)
Galley and Food		5952.5		22.516
Food	2.3 kg/p/d	5175.0	0.008 m ³ /p/d	18.000
Freezer(s)	400 kg	400	2.000 m ³	2.000
Conventional ovens	50 kg	50	0.250 m ³	0.250
Microwave ovens	70 kg	70	0.300 m ³	0.300
Cleaning supplies	0.25 kg/d	187.50	0.002 m ³ /d	1.350
Sink and spigot	15 kg	15	0.014 m ³	0.014
Dishwasher	40 kg	40	1 m ³	1
Cooking/eating supplies	5 kg/p	15	0.014 m ³ /p	0.042
Waste Collection		720.0		9.085
System	90 kg	90	4.360 m ³	4.360
Supplies	0.05 kg/p/d	112.50	0.001 m ³ /p/d	2.925
Contingency collection mittens/bags	0.23 kg/p/d	517.5	0.001 m ³ /p/d	1.800
Shower	75 kg	75	1.140 m ³	1.140
Handwash/mouthwash faucet	8 kg	8	0.010 m ³	0.010
Personal hygiene kit	1.8 kg/p	5.4	0.005 m ³ /p	0.015
Hygiene consumables	0.075 kg/p/d	168.8	0.002 m ³ /p/d	3.375
Clothing (review notes in factors sheets to determine trades)		259		2.508
Clothing	99 kg/p	99	0.336 m ³ /p	1.008
Washing machine	100 kg	100	1 m ³	1
Clothes dryer	60 kg	60	1 m ³	1



Crew Accommodations Model

Mission Type: Mars Habitation | Crew Size: 3 | Duration 750 days

Crew Accommodations System		Mass Factor (see sheet 2)	Mass Subtotal (kg)	Volume Factor (see sheet 3)	Volume Subtotal (m ³)
Recreational Equipment			150		0.750
Personal storage		50 kg/p	150	0.750 m ³	0.750
Housekeeping			275.5		2.620
Vacuum		13 kg	13	0.070 m ³	0.070
Disposable wipes for housecleaning		0 kg/p/d	0	0.000 m ³ /p/d	0.000
Trash compactor/trash lock		150 kg	150	0.300 m ³	0.300
Trash bags		0.05 kg/p/d	112.50	0.001 m ³ /p/d	2.250
Operational Supplies and Restraints			160		0.546
Operational supplies		20 kg/p	60	0.002 m ³ /p	0.006
Restraints		100 kg	100	0.540 m ³ /kg	0.540
Maintenance			1800		7.500
Hand tools and accessories		300 kg	300	1.000 m ³	1.000
Spare parts and consumables		-	0	- m ³	0
Test equipment		500 kg	500	1.500 m ³	1.500
Fixtures, large machine tools, gloveboxes, etc		1000 kg	1000	5.000 m ³	5.000
Photography			120		0.500
Equipment		120 kg	120	0.500 m ³	0.500
Sleep Accommodations			27		0.300
Sleep provisions		9 kg/p	27	0.100 m ³ /p	0.300
Exercise equipment		145 kg	145	0.190 m ³	0.190
Medical/surgical/dental suite		1000 kg	1000	4.000 m ³	4.000
Medical/surgical/dental consumables		500 kg	500	2.500 m ³	2.500
TOTAL (kg)			11366.2	TOTAL (m³)	57.55



Model Estimations

For test case, chose the Mars Habitation mission type

- Although it is planetary and not orbital, estimations are largely driven by need to be autonomous

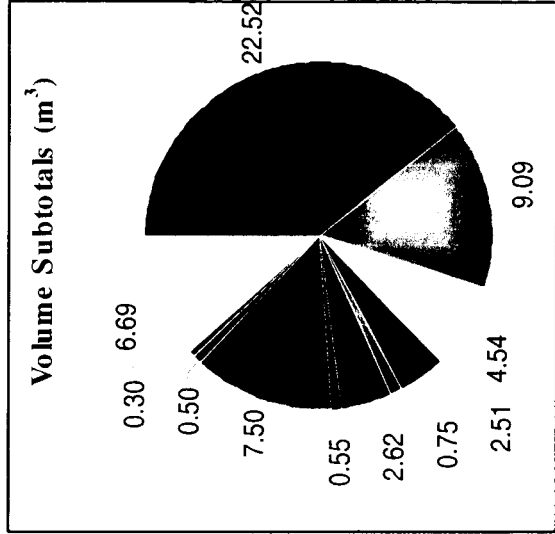
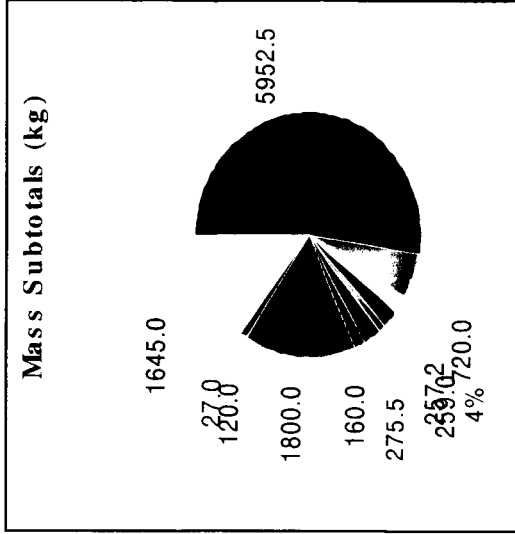
750 days	11366 kg	58 m ³
1110 days	14378 kg	72 m ³
1470 days	17389 kg	86 m ³



Mission type: **4**
 Crew Size: **3**
 Duration (days): **750**

System	Mass Subtotal (kg)	Percent Total Mass (kg)
Galley and Food	5952.5	52.4
Waste Collection	720.0	6.3
Personal Hygiene	257.2	2.3
Clothing	259.0	2.3
Recreation	150.0	1.3
Housekeeping	275.5	2.4
Operations	160.0	1.4
Maintenance	1800.0	15.8
Photography	120.0	1.1
Sleep Accommodations	27.0	0.2
Crew Health Care	1645.0	14.5
TOTAL	11366.2	100.0

System	Volume Subtotal (m ³)	Percent Total Volume (m ³)
Galley and Food	22.52	39.1
Waste Collection	9.09	15.8
Personal Hygiene	4.54	7.9
Clothing	2.51	4.4
Recreation	0.75	1.3
Housekeeping	2.62	4.6
Operations	0.55	0.9
Maintenance	7.50	13.0
Photography	0.50	0.9
Sleep Accommodations	0.30	0.5
Crew Health Care	6.69	11.6
TOTAL	57.55	100.0





Mission type:

4

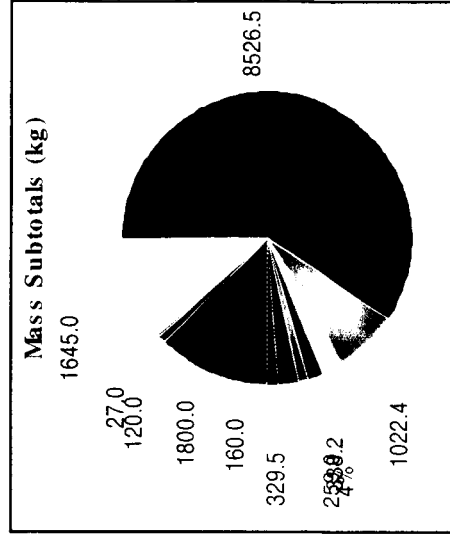
Crew Size:

3

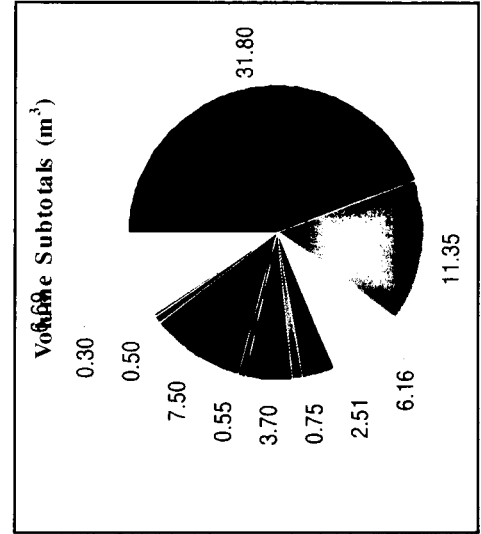
Duration (days):

1110

System	Mass Subtotal (kg)	Percent Total Mass (kg)
Galley and Food	8526.5	59.3
Waste Collection	1022.4	7.1
Personal Hygiene	338.2	2.4
Clothing	259.0	1.8
Recreation	150.0	1.0
Housekeeping	329.5	2.3
Operations	160.0	1.1
Maintenance	1800.0	12.5
Photography	120.0	0.8
Sleep Accommodations	27.0	0.2
Crew Health Care	1645.0	11.4
TOTAL	14377.6	100.0



System	Volume Subtotal (m ³)	Percent Total Volume (m ³)
Galley and Food	31.80	44.3
Waste Collection	11.35	15.8
Personal Hygiene	6.16	8.6
Clothing	2.51	3.5
Recreation	0.75	1.0
Housekeeping	3.70	5.2
Operations	0.55	0.8
Maintenance	7.50	10.4
Photography	0.50	0.7
Sleep Accommodations	0.30	0.4
Crew Health Care	6.69	9.3
TOTAL	71.81	100.0



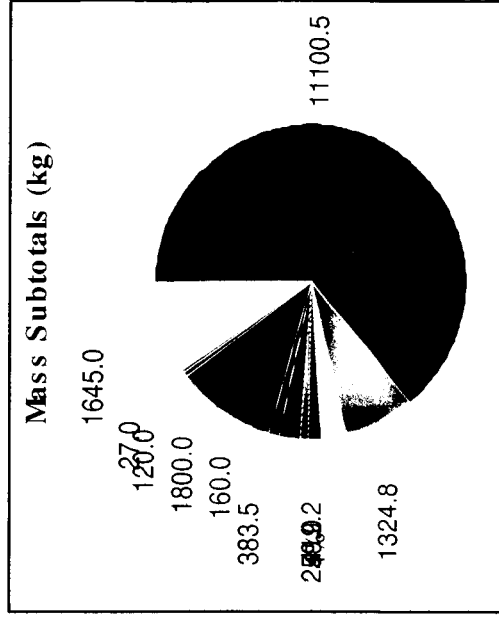


Mission type: **4**

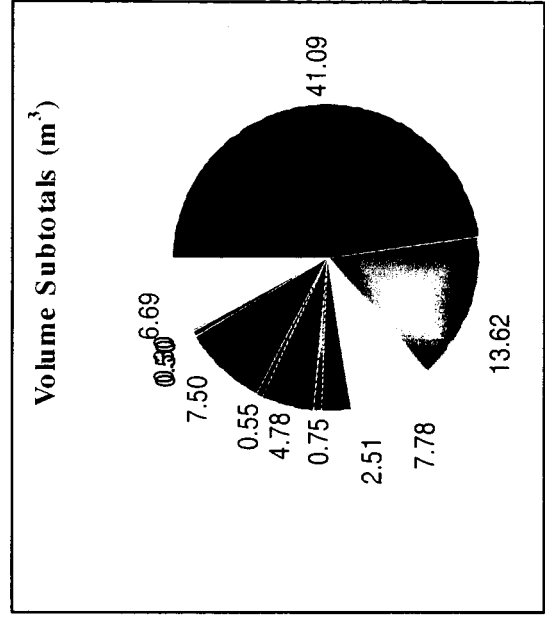
Crew Size: **3**

Duration (days): **1470**

System	Mass Subtotal (kg)	Percent Total Mass (kg)
Galley and Food	11100.5	63.8
Waste Collection	1324.8	7.6
Personal Hygiene	419.2	2.4
Clothing	259.0	1.5
Recreation	150.0	0.9
Housekeeping	383.5	2.2
Operations	160.0	0.9
Maintenance	1800.0	10.4
Photography	120.0	0.7
Sleep Accommodations	27.0	0.2
Crew Health Care	1645.0	9.5
TOTAL	17389.0	100.0



System	Volume Subtotal (m ³)	Percent Total Volume (m ³)
Galley and Food	41.09	47.7
Waste Collection	13.62	15.8
Personal Hygiene	7.78	9.0
Clothing	2.51	2.9
Recreation	0.75	0.9
Housekeeping	4.78	5.6
Operations	0.55	0.6
Maintenance	7.50	8.7
Photography	0.50	0.6
Sleep Accommodations	0.30	0.3
Crew Health Care	6.69	7.8
TOTAL	86.07	100.0





Model Exclusions

Model excludes some crew accommodation resources

- Potable and hygiene water
- Spare
- Integration hardware
- Contingency supplies

Test case requires estimate of total vehicle mass & volume necessary to support human operations/presence

- Air
- Emergency supplies
- Radiation shelter
- Extravehicular equipment
- Tools
- Science
- Systems (thermal, environmental, electrical, communication)



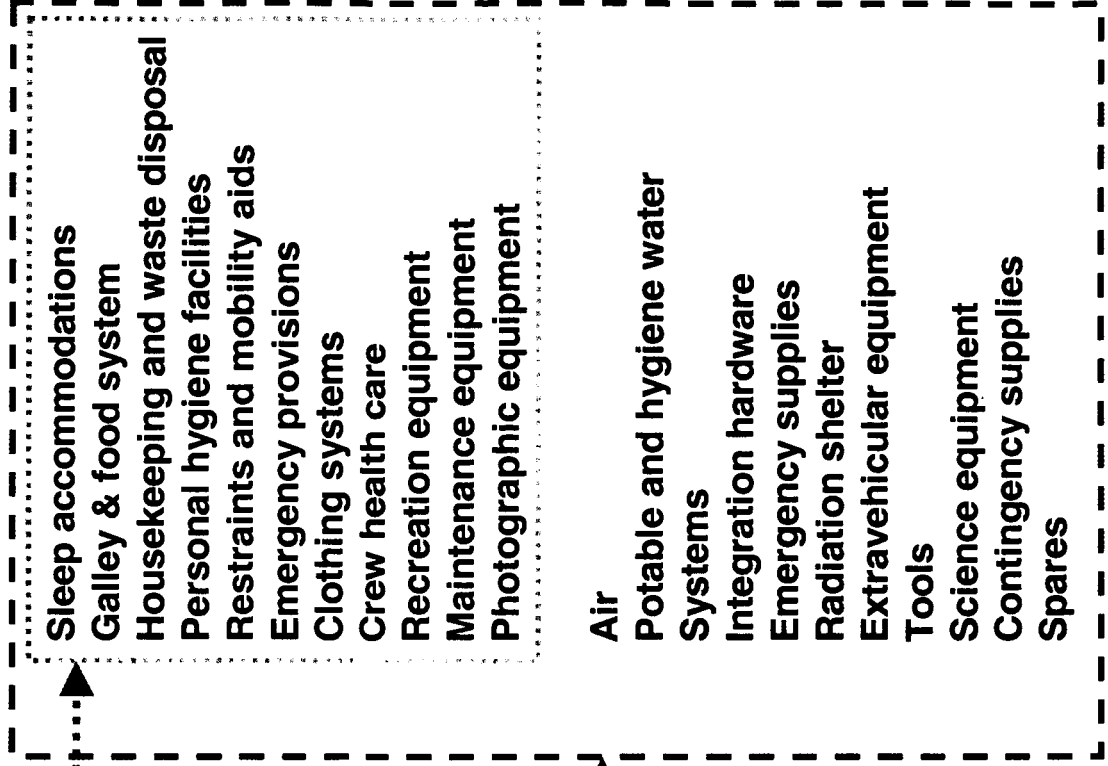
Modified Estimations

Crew Accommodations Estimates

750 days	11366 kg	58 m ³
1110 days	14378 kg	72 m ³
1470 days	17389 kg	86 m ³

Total estimates with additional parameters**

750 days	71304 kg	361 m ³
1110 days	89791 kg	469 m ³
1470 days	108279 kg	578 m ³



***These are initial estimates which have not been validated or confirmed*



Conclusions

Crew Accommodations Resource Model* *instrumental* in deriving volume & mass for a long duration human space flight

However, it accounts for only one relatively small portion of total vehicle or habitat resource estimation

May be useful to include in a new model for total spacecraft volume & mass estimation

Value-added:

- Increase the accuracy of human space flight research and development
- Act as a cost saving measure by preventing inaccurate assumptions from driving design decisions



* Stillwell, D., Boutros, R., & Connolly, J. (1999) "Crew Accommodations". In Larson & Pranke (Eds.) Human Spaceflight Mission Analysis and Design (Space Technology Series), McGraw-Hill, Inc.



Thank You!

Please feel free to
contact me with any
questions.

Jennifer Linda Blume, Ph. D.
Human Engineering & Analysis Team
NASA-Marshall Space Flight Center
Allied Aerospace Industries, Jacobs Sverdrup MSFC Group
jennifer.l.blume@msfc.nasa.gov
256.544.5491

