Lockheed Martin Space Mission Systems & Services
Science, Engineering, Analysis, and Test
2400 NASA Road 1, P.O. Box 58561, Houston, TX 77258-8561
Telephone (281) 333-5411

LOCKHEED MARTIN

MSAD – 00 – 0089

To: M. K. Ewert /EC2

09 December 1999
Contract: NAS9–19100
Subtask Order: 0 HECECAYS

Via: J. L. Cox /B08
J. F. Keener /C70 *Original initialed by: JFK*
F. F. Jeng /C70 *Original initialed by: FFJ*
From: A. J. Hanford /C70 *Original initialed by: AJH*

Subject: Summary of the Rapid Technology Assessment Meeting, December 1999

Attached is a memorandum titled "Summary of the Rapid Technology Assessment Meeting, December 1999." This memorandum details the discussions associated with the Rapid Technology Assessment Meeting held at Lockheed Martin in Houston in December, 1999.

The meeting and this memorandum were supported and prepared by the author under subtask order 0 HECECAYS.

Any questions or comments should be referred to the author at (281) 333-6525 (tony.hanford@lmco.com).

Anthony J. Hanford

Rapid Technology Assessment Meeting

2-3 December 1999

Lockheed Martin, 2400 NASA Road One, LM23B3, Houston, Texas

Point of Contact: Anthony J. Hanford, (281) 333-6525 or tony.hanford@lmco.com

In attendance:

Dr. Alan Drysdale	The Boeing Company/KSC
Bruce Duffield	Lockheed Martin/JSC
Mike Ewert	NASA/JSC/EC2
Dr. Cory Finn	NASA/ARC
Dr. A. J. Hanford	Lockheed Martin/JSC
Frank Jeng	Lockheed Martin/JSC
John Keener	Lockheed Martin/JSC
Dr. Kevin Lange	Lockheed Martin/JSC
Dr. Chin Lin	NASA/JSC/EC2
Jannivine Yeh	Lockheed Martin/JSC

The Meeting Agenda provides a breakdown of the scheduled topics in the order they were addressed. The principle facilitator or presenter for each topic is noted to the right. In general, each presentation initiated discussion by the group as a whole, and the topics of greatest interest and concern are noted under Discussion Topics. The final topic, Action Items, provides a list of activities which should help to address some of the issues noted during the discussion. The individual who is tentatively responsible for each action item is noted in parentheses.

Meeting Agenda:

- Introduction and Purpose — M. Ewert
- Life Support Straw Man Designs for Reference Missions — A. Hanford
- Role of System Architecture Studies in Technology Assessment — K. Lange
- Comparison of Straw Man Design to Dual Lander LSS — Group
- Boeing's Equivalent System Mass Spreadsheet Models — A. Drysdale
- Details of ALS Metric Baseline Computation — A. Drysdale
- Lockheed Martin's ECLSS Sizing Spreadsheet Model — J. Yeh
- The Role of Dynamic Modeling in Technology Assessment — C. Finn
- Technology Evaluation Matrix Candidate Technologies List — B. Duffield
- Discussion of an Approach for Rapid Technology Evaluation — Group

Discussion Topics:

- The contingency and redundancy philosophy for the reference missions is undefined. As such masses can add up to ten percent or more to the overall equivalent system mass for a life support system, this should be specified and included in future studies.
- The start up scenario and staffing schedule for the Evolved Mars Base is undefined. While initially these aspects were to be undefined, the start up and staffing schedule may have a significant impact on the economic viability of some life support technologies so these aspects should be defined. However, as in-situ resource utilization (ISRU) is not assured for a Mars Base, however attractive it might be, the baseline start-up scenario should not assume extensive inputs from ISRU. More specifically, if one assumes that ISRU will provide life support consumables from the Martian atmosphere alone to allow the crew to operate in an "open loop" mode for the entire mission, the water requirement will drive any ISRU system sizing.
- Comparison of the ALS Straw Man for an exploration mission with the documentation under preparation describing the environmental control and life support system (ECLSS) from the Exploration Office's Dual-Lander Exploration Architecture yielded a high level of agreement. Some differences were noted and these will be reflected in the Reference Missions Document.
- The ALS Reference Missions Document draft (JSC-39502) currently does not contain flow diagrams for the life support system architecture designs. To make the document more useful to analysts and researchers, fairly detailed diagrams, including all major tanks and process flow streams, should be included for at least the ALS Straw Man Designs. Corresponding diagrams for the designs using International Space Station (ISS) ECLSS technologies are also desirable both as a reference and to insure that the proposed baseline systems and mass assessments are indeed complete. As part of the current technology assessment task, K. Lange will review existing life support system architecture designs, as well as develop new designs. As appropriate, K. Lange's work will be incorporated into the ALS Reference Missions Document and other SMAP documentation.
- It appears that the Exploration Office has "replaced" the Combo-Lander mission architecture with the Dual-Lander mission architecture. While the latter is not well documented yet, the ALS Reference Missions Document should reflect this latter mission and possibly delete the former approach. However, for the current fiscal year, the Combo-Lander should remain in the ALS literature to explain more fully the mission assumed for the corresponding assessment in the current ALS Metric document.
- Near-term, the Exploration Office may also consider missions to other near-Earth destinations other than Mars, including Luna, near-Earth asteroids, and the Martian moons. As mission planning information becomes available, these too should be added to the ALS Reference Missions Document. Until such

information is available, however, many of these destinations might be addressed as special cases of a transportation mission to Mars.

- Dynamic modeling is an important tool for checking system performance and for sizing system buffers. For overall system analysis of a bioregenerative life support system with a plant growth chamber, current computational assets running Matlab/Simulink can reasonably handle time scales on the order of a day. Such a large time scale is not sufficient to accurately model the dynamics of physicochemical systems that have characteristic times on the order of minutes or hours. Time scales on the order of one day are sufficient to accurately size buffers associated with plant growth modules as crop plants take thirty days or longer to reach maturity. Dynamic modeling using Matlab/Simulink or other software might independently consider subsystems of physicochemical equipment, especially to address sizing for tankage and matching processing rates for multi-component process streams. Overall, dynamic modeling provides invaluable support. However, because most issues associated with top-level system analysis, the primary format employed for the equivalent system mass assessments within the rapid technology assessment process, are handled with sufficient accuracy within spreadsheet models, dynamic modeling should be employed only as needed.

- Several formats can be used to organize and define life support subsystems. To facilitate future studies, the group discussed defining a common life support subsystem list. As the ALS Project is already divided into a number of subsystem groups, any new organization should incorporate this status quo both to facilitate approval by the ALS Project and to ease the transitional process. A tentative list was developed and circulated for comment and revision. Six subsystems and six eternal interfaces were identified. The six ALS subsystems are air, biomass production, food, thermal control, waste, and water. These subsystems interact with six interfaces including extravehicular activity support, human accommodations, integrated control, in-situ resource utilization, power, and radiation protection. These subsystems have been summarized more completely in Table 1 amended to the end of this document.

- The ALS technology assessment is in progress with a report due at the end of government fiscal year 2000. The assessment, as currently envisioned, will proceed in three steps. The first step is to identify candidate life support system architecture designs for the initial BIO-Plex test and for the reference missions. As the BIO-Plex's initial testing will, based on current thinking, support near-term, exploration missions for the Martian surface, priority will be given to developing architectures for Mars Exploration missions such as the Dual-Lander format. The second step will identify technologies that are appropriate for each candidate architecture. A qualitative assessment, focusing on advantages and disadvantages of each potential life support technology, was suggested. This option will be reviewed, and implemented if appropriate, as part of the assessment process. The third step of the process will provide equivalent system mass studies for the most promising technologies identified in the second step.

Action Items:

- **Contingency** *(Unassigned)*: Develop contingency and redundancy philosophies for the ALS reference missions.
- **Start Up** *(Unassigned)*: Develop start up and realistic staffing scenarios for the Evolved Mars Base reference mission. Extensive inputs from ISRU are not allowed as part of the baseline scenarios.
- **ALS Straw Man Updates** *(Lockheed Martin/JSC)*: Update the ALS Reference Missions Document to reflect updates and corrections based on analysis of the Dual-Lander ECLSS documentation.
- **LSS Diagrams** *(Lockheed Martin/JSC)*: Develop schematics of the proposed ALS Straw Man Life Support Designs for the ALS Reference Missions Document. Similar schematics for the designs using ISS ECLSS technologies are desirable.
- **Dual-Lander** *(Unassigned; Possibly Lockheed Martin/JSC)*: Add the Dual-Lander mission to the ALS Reference Missions Document either to augment or to replace the Combo-Lander reference mission that is in the current document draft. The document Frank Jeng is compiling in support of the Exploration Office for the Dual-Lander study may be of use. This should be completed by January 2000.
- **Other Missions** *(Unassigned; Possibly Lockheed Martin/JSC)*: Add other missions for near-Earth destinations, such as Luna, near-Earth asteroids, and the Martian moons, to the ALS Reference Missions Document as appropriate information becomes available from the Exploration Office.
- **ALS Subsystem Description** *(NASA/JSC)*: Seek ALS Project approval and formal implementation for the proposed Life Support Subsystem Breakdown.
- **ALS Technology Assessment** *(Lockheed Martin/JSC)*: Formulate and deliver a technology assessment of advanced life support equipment for reasonably likely near-term human missions to Mars. Forward the resulting technology selection to the ALS Project and BIO-Plex.

Table 1 ALS Project Life Support Subsystem Breakdown (Proposed)

Subsystem	Description	Internal Life Support System Interfaces
Air	The Air Subsystem stores and maintains the vehicle cabin gases, including the overall composition and atmospheric pressure. The Air Subsystem is also responsible for fire detection and suppression.	Biomass Production, Food, Thermal Control, Waste, Water, EVA Support, Human Accommodations, In-Situ Resource Utilization, Internal Control, Power
Biomass Production	The Biomass Production Subsystem provides raw agricultural products to the Food Subsystem while regenerating air and water. This subsystem is not present in a solely physicochemical life support system.	Air, Food, Thermal Control, Waste, Water, In-Situ Resource Utilization, Integrated Control, Power
Food	The Food Subsystem stores and transforms raw or bulk agricultural products into ready-to-eat food.	Air, Biomass Production, Thermal Control, Waste, Water, EVA Support, Human Accommodations, Integrated Control, Power
Thermal Control	The Thermal Control Subsystem is responsible for maintaining cabin temperature and humidity within appropriate bounds and for rejecting the collected waste heat to the environment.	Air, Biomass Production, Food, Waste, Water, Human Accommodations, Integrated Control, Power
Waste	The Waste Subsystem stores and handles waste material waste products produced anywhere in the life support system, including packaging, human wastes, inedible biomass, and brines from other subsystems such as the Water Subsystem. The Waste Subsystem may sterilize and store the waste, or reclaim life support commodities, depending on the life support system closure and/or mission duration.	Air, Biomass Production, Food, Thermal Control, Water, EVA Support, Radiation Production, Integrated Control, Human Accommodations, Power
Water	The Water Subsystem stores and provides water at the appropriate purity for crew consumption and hygiene.	Air, Biomass Production, Food, Thermal Control, Waste, EVA Support, Human Accommodations, In-Situ Resource Utilization, Integrated Control, Power, Radiation Protection

External Life Support Interfaces	Description	External Life Support System Interfaces
Extravehicular Activity (EVA) Support	The EVA Support Interface provides life support consumables for EVA, including oxygen, water, and food, and carbon dioxide and waste removal, for extravehicular activities.	Air, Food, Waste, Water, Human Accommodations, Integrated Control, Power
Human Accommodations	The Human Accommodations Interface is responsible for the crew cabin layout, crew clothing including laundering, and the crew's interaction with the life support system.	Air, Biomass Production, Food, Thermal Control, Waste, Water, EVA Support, Integrated Control, Power
In-Situ Resource Utilization	The In-Situ Resource Utilization Interface provides life support commodities, such as gases, water, and regolith, for use throughout the life support system.	Air, Biomass Production, Water, Integrated Control, Radiation Protection, Power
Integrated Control	The Integrated Control Interface provides appropriate control for the life support system.	ALL
Power	The Power Interface provides the necessary energy to support all equipment and functions within the life support system.	ALL
Radiation Protection	The Radiation Protection Interface provides protection from environmental radiation.	Food, Waste, Water, In-Situ Resource Utilization, Power

Distribution

NASA Lyndon B. Johnson Space Center

Recipient	(Copies)	Mail Code
Cox, J. L.		B08
Duffield, B.		C70
Ewert, M. K.	(3)	EC2
Gertner, B.		C70
Hanford, A. J.	(3)	C70
Jeng, F. F.		C70
Jerng, L.		C70
Keener, J. F.		C70
Lange, K.		C70
Lin, C. H.		EC2
McGlothlin, E. P.		C70
Weaver, G.		C70
Yeh, J.		C70
Job Order File	(2)	C70

NASA Ames Research Center
Moffett Field, CA 94035-1000

Recipient	(Copies)	Mail Code
Finn, C. K.		239-8
Jones, H.		239-8

The Boeing Company
P. O. Box 21233, Kennedy Space Center, FL 32815

Recipient	(Copies)	Mail Code
Drysdale, A. E.		KA91 F530
Maxwell, S.		KA91 F530