Decision Support Systems for Research and Management in Advanced Life Support

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Abstract

Decision support systems have been implemented in many applications including strategic planning for battlefield scenarios, corporate decision making for business planning, production planning and control systems, and recommendation generators like those on Amazon.com®. Such tools are reviewed for developing a similar tool for NASA's ALS Program. DSS are considered concurrently with the development of the OPIS system, a database designed for chronicling of research and development in ALS. By utilizing the OPIS database, it is anticipated that decision support can be provided to increase the quality of decisions by ALS managers and researchers.

Keywords
Decision support systems, online analytical processing, management information systems, Advanced Life Support Systems

1. Introduction

An extensive history exists regarding the development of systems for decision support. Included in the literature are decisions support systems (DSS) in strategic planning for large corporations, in battlefield scenarios for the military, and in foreign policy development for international politics, in production planning and control systems, and in the quality of participants in the online trading community eBay Inc. [4]. Additional online decision support tools include the recommendation generation tools provided by websites such as Amazon.com® [1], which suggest purchases to their customers based on their customers previous activity on the website. These represent a broad array of applications of DSS. It is proposed that such systems could be utilized to enhance the research and development of Advanced Life Support (ALS) systems for NASA.

It is natural to desire to improve the quality of decision-making. Improved decision-making suggests greater success in all areas, whether that is on the battlefield, in the Whitehouse, in the boardroom, on the factory floor, or making purchases online. It follows then that the research and development of innovative ways to support and improve the decision-making process is an active field of inquiry.

In NASA's case, the research and development of innovative systems presents many challenges. These challenges are further compounded by a relatively limited budget, which is called upon to fund highly risky, extremely costly, far reaching research endeavors. Inevitably, difficult decisions need to be made and in the absence of prior experience, which is predominantly the case for NASA projects, justification for decision-making can be difficult to find. In addition, NASA's ALS Program has been criticized for a lack of a rigorous technology selection process highlighting the need for effective decision support.

The development of DSS requires a thorough understanding of the task the system will support. In the case of ALS, three distinct decision support tasks exist: (1) where a new investigator searches potential research needs while developing a research plan for ALS, (2) where an existing ALS investigator wishes to gauge the state of his/her research activities within the ALS Community, and (3) where ALS Management allocates its resources over the short- and long-term in an effort to develop ALS systems. The intention of a DSS implemented here would be to enable the rapid attainment of ALS Program goals through well-informed research decisions and enhanced management decisions.

Concurrent with the effort to consider decision support for the ALS Program, there exists an effort to implement a database repository of ALS project information. The intention of the database, called the Online Project Information

System (OPIS), is to assist ALS Management in technology selection and to assist researchers in determining programmatic needs by making information describing ALS research readily available. Such a database can serve as the knowledge base for a decision support system that will support the goals of the OPIS platform.

2. Background

2.1. NASA's Advanced Life Support Program

Human space missions are increasing in duration and complexity with the advent of the International Space Station and the prospect of long duration missions to the Moon and Mars in the future [2]. With increasing duration, it becomes less economical and practical to resupply basic life support elements from Earth [12], especially as the distance from the Earth also increases. NASA and the international space community have been actively investigating technologies to enable such missions since the 1950's, including the ability to purify the water supply and regenerate a breathable atmosphere. Ultimately, such a system would be a closed system, perhaps centered around a crop growth system, capable of contributing to water purification, air revitalization, processing waste materials, as well as providing a food source for the crew. Within NASA, the ALS Program is charged with the research and development of the technologies to enable these systems. NASA's ALS Program currently investigates the growth of crops for food and oxygen production, and the use of physicochemical and biological technology for recycling waste materials into reusable resources (Table 1). In addition, several integrated tests have been completed where human test subjects and ALS technologies were included to determine efficiency, reliability, and the effectiveness of the regenerative systems. Based on past successes, a new program, the Advanced Integration Matrix (AIM), will continue to test ALS technologies in integrated human tests for the purpose of enabling long-duration human missions to the Moon and Mars.

Table 1. Research elements in NASA's ALS Program and descriptions

Element	Description
Air	Responsible for the storage and maintenance of cabin atmosphere
Biomass	Responsible for the production, storage, and provision of raw agricultural products
Food	Responsible for the stabilization and processing of raw agricultural products and prepackaged food items into ready-to-eat forms
Thermal	Responsible for maintaining cabin temperature and humidity within appropriate bounds and rejecting collected waste heat to the Cooling Interface
Waste	Responsible for the collection of solid waste material from within the habitat for microbial inactivation, stabilization, recovery, storage, or disposal.
Water	Responsible for the collection of wastewater from within the habitat and recovers and provides water at the appropriate purity for its intended use, including potable water for crew consumption.

In addition, the understanding of two conventions within NASA ALS is required to understand the potential for decision support in ALS: (1) equivalent system mass (ESM) and (2) technology readiness level (TRL). ESM is a cost related metric [8]. It is a function of the mass, power, volume, cooling, and crew time requirements of a proposed system. High ESM suggest that there will be a high launch payload mass, a factor NASA endeavors to minimize. TRL is a metric rating the state of knowledge describing a given technology (Table 2) [6]. Generally, only technologies of TRL 8 or 9 are considered for inclusion in a mission. The thrust of ALS research activity is to raise the TRL of technology to approximately level 6 with minimal ESM, so that the technology can be adopted by a flight program for further development and eventual adoption into a mission.

Table 2. Technology Readiness Levels

TRL	Description
1	Basic principles observed and reported.
2	Technology Concept and/or application formulated.
3	Analytical and experimental critical function and/or characteristic proof-of-concept.
4	Component and/or breadboard validation in laboratory environment.
5	Component and/or breadboard validation in relevant environment.
6	System/subsystem model or prototype demonstration in relevant environment (ground or space).
7	System prototype demonstration in a space environment.
8	Actual system completed and "flight qualified" through test and demonstration.
9	Actual system "flight proven" through successful mission operations.