

# The Function-Specific Level of Autonomy and Automation Tool

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NASA's Vision for Space Exploration will significantly alter the design of the next human spaceflight vehicle. The Crew Exploration Vehicle (CEV) will be designed at higher levels of autonomy and automation than previous NASA vehicles due to: the long time lag in communications, vast computer enhancements, the emergence of highly reliable decision-making

algorithms, and an increased emphasis on efficiency. At the center of this evolution in vehicle design are the questions, "What is the right balance of ground vs. onboard authority (autonomy)?" and "What is the right balance of human vs. computer authority (automation)?" To answer these questions, a team of NASA/JSC Mission Operations and Engineering

## Autonomy and Automation Scales

Level	Observe	Orient	Decide	Act
7	The computer gathers, filters, and prioritizes data without displaying any information to the human.	The computer predicts, interprets, and integrates data into a result which is not displayed to the human.	The computer performs final ranking, but does not display results to the human.	Computer executes automatically and does not allow any human interaction.
6	The computer gathers, filters, and prioritizes data without displaying any information to the human. Through a "program functioning" flag is displayed.	The computer analyzes, predicts, interprets, and integrates data into a result which is only displayed to the human if result fits programmed context (context dependant summaries).	The computer performs final ranking and displays a reduced set of ranked options without displaying "why" decisions were made to the human.	Computer executes automatically and only informs the human if required by context. It allows for override ability after execution. Human is shadow for contingencies.
5	The computer is responsible for gathering and displaying unfiltered, unprioritized information for the human. The human still is the prime monitor for all information.	The computer overlays predictions with analysis and interprets the data. The human is shown all results.	The computer performs ranking tasks and displays a reduced set of ranked options while displaying "why" decisions were made to the human.	Computer executes automatically, informs the human, and allows for override ability after execution. Human is shadow for contingencies.
4	The computer is responsible for gathering and displaying unfiltered, unprioritized information for the user.	The computer overlays predictions with analysis and interprets the data. The human shadows the interpretation for contingencies.	The computer performs ranking tasks. All results, including "why" decisions were made, are displayed to the human.	Computer allows the human a context-dependent restricted time to veto before execution. Human shadows for contingencies.
3	The computer is responsible for gathering and displaying unfiltered, unprioritized information for the human. The human still is the prime monitor for all information.	Computer is the prime source of analysis and predictions, with computer shadow for interpretation of the data.	Both human and computer perform ranking tasks, the results from the human are considered prime.	Computer executes decision after human approval. Human shadows for contingencies.
2	Human is the prime source for gathering and monitoring all data, with computer shadow for emergencies.	Human is the prime source of analysis and predictions, with computer shadow for contingencies. The human is responsible for interpretation of the data.	The human performs all ranking tasks, but the computer can be used as a tool for assistance.	Human is the prime source of execution, with computer shadow for contingencies.
1	Human is the only source for gathering and monitoring (defined as filtering, prioritizing and understanding) all data.	Human is responsible for analyzing all data, making predictions, and interpretation of the data.	The computer does not assist in or perform ranking tasks. Human must do all.	Human alone can execute decision.

  

Level	Observe	Orient	Decide	Act
5	The data is monitored onboard without assistance from ground support	The calculations are performed onboard without assistance from ground support	The decision is made onboard without assistance from ground support	The task is executed onboard without assistance from ground support
4	The majority of the monitoring will be performed onboard with available assistance from ground support	The majority of the calculations will be performed onboard with available assistance from ground support	The decision will be performed onboard with available assistance from ground support	The task is executed onboard with available assistance from ground support
3	The data is monitored both onboard and on the ground.	The calculations are performed both onboard and on the ground.	The decision is made both onboard and on the ground and the final decision is negotiated between them.	The task is executed with both onboard and ground support.
2	The majority of the monitoring will be performed by ground support with available assistance onboard	The majority of the calculations will be performed by ground support with available assistance onboard	The decision will be made by ground support with available assistance onboard	The task is executed by ground support with available assistance onboard
1	The data is monitored on the ground without assistance from onboard	The calculations are performed on the ground without assistance from onboard	The decision is made on the ground without assistance from onboard	The task is executed by ground support without assistance from onboard

## Questionnaire = FLOAT

**Automation Survey**

User: **Jeremy Hart**  
 Function: Rank Available Launch Targets [Decide]

Use the submit button at the bottom of the page to register the survey responses. The survey responses are not saved without selecting the submit button. The survey can always be returned to for further editing once saved.

Category	Question	Answer					Comments
		High (res)	Mod High	Mod Low	Low (no)		
Ability	Question: What is the expected ability of developers to correctly design the function for all possibilities within the design phase deadlines?  Notes: Expected ability of designers to completely define the world of possibilities that this function will face, before the final deadline. Ability is defined as able to do the job, not the designer's ability level.  Example: Designers would have low ability to design the hardest or rewest functions. Thus, hard or new functions would be low on the ability scale. Though, easy functions or functions that we have been doing for years would be high in ability.	<input type="radio"/>					
Ability	Question: What is the expected ability of programmers to correctly implement the design within the implementation deadlines?  Notes: Expected ability of software writers to completely code the design that the developers handed them, regardless of the size of the world that was defined in the design phase, before the final deadline. Ability is defined as able to do the job, not the programmer's ability level.  Example: If the developers are only going to design for a limited set of cases, it makes it more likely that the software writers will be able to code it in by the deadline.	<input type="radio"/>					
Difficulty	Question: What is the expected effort of developers to correctly design the function for all possibilities within the design phase deadlines?  Notes: This is the same as the above questions, but the focus is not on "how good will the design be?" but on "how hard will it be to design?"  Example: Hard (high) designs start from scratch or incorporate new ideas where expectations are not well-defined. Easy (low) designs have already been used in this context.	<input type="radio"/>					

Directorate personnel have developed the Function-specific Level of Autonomy and Automation Tool (FLOAAT), as shown in the figure.

FLOAAT is a quantitative assessment tool that was originally developed for use during the design process to determine the appropriate levels of autonomy and automation to be included in the system-level requirements. It can also be used after NASA's requirements have been developed for contractor proposal evaluations by comparing contractor proposed designs to NASA's expected results. In either application, the process of using FLOAAT will result in a clearly defined, baseline balance of authority. The process uses domain-specific experts to qualitatively evaluate a set of functionally decomposed vehicle requirements using a questionnaire that yields a quantitative solution similar to the Cooper-Harper Scale or the Bedford Workload Scale. The quantitative solution maps to the set of FLOAAT Level of Autonomy and Automation Scales to provide a precise, clear, and easy-to-understand definition for the different levels of autonomy and automation. The scales show separate levels of automation and autonomy for each of the 4 stages of decision-making (Observe, Orient, Decide, and Act).

FLOAAT adapts and advances many academic and theoretical constructs into a practical application that will aid in the design of a vehicle. One important practical lesson is that users trust in the software often dictates how it is used more than software capability. This duality led us to split our tool into trust issues and cost/benefit issues. Trust issues include: software complexity, robustness, experience, understandability, art vs. science, training, etc. Cost/benefit issues include: usefulness, timeliness, criticality/safety, development costs, sustaining costs, efficiency, etc. The output from FLOAAT gives both limits for autonomy and automation based solely on trust issues and limits for autonomy and automation based solely on cost/benefit issues. The cost/benefit limit and the trust limit must be compared to find the true answer. For example, if the cost/benefit limit is higher (more automated) than the trust limit, then, even though it may be cost effective to implement an automated system at the cost/benefit limit, humans will not trust the system at that level. Since trust is the limiting factor, either the system should be automated to the trust limit or the trust issues should be resolved through test projects and education of the users until the trust limit increases to equal the cost/benefit limit.

FLOAAT has established itself as a viable technique for determining appropriate levels of autonomy and automation for crewed vehicles. FLOAAT is positioned to become the standard method for balancing human vs. computer authority and ground vs. onboard authority for vehicle design.