DRAFT

# ALFUS Workshop #7 Summary
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## 1. Executive Summary

The ALFUS model development is the focus of this workshop. On the detailed model, LSI presented the metric based autonomy level evaluation tool (a big Thank You, Charlie and Chiraq). On the summary/executive model, the workshop participants brainstormed and drafted definitions for several key levels, based on Hui's strawman definitions.

These three metrics development subgroup are urged to document the guidelines for integrating to the tool. A schedule will be distributed separately. The target is to show version 2 of the tool, containing these features, in ALFUS Workshop #8, planned for late January 2005.

Your opinions are requested on all the interim progress.

## 2. Model Development

The ALFUS model development is the focus of this workshop. The detailed model will be realized with the autonomy level tool that Charlie B./Chiraq T. would present. The summary/executive model would be developed as tables and descriptors. Both are critical but for different users.

### *2.1. Detailed Model—Autonomy Level Evaluation Tool*

Chiraq Tasker of SAIC ably represented Charlie B. (both with LSI) and presented the autonomy level evaluation tool that Charlie has been creating. The tool is implemented on Excel spreadsheet. There are four worksheets for the tool, summary, complexity, environment, and human interaction. The FCS Autonomous Navigation System was used as an illustration. The autonomous driving task was decomposed into layers of subtasks. In the complexity sheet, each subtask was evaluated and scored against all the metrics on the axis. Each subtask is then weighted for the subtask scores to be averaged into task scores. The tasks are also weighted so that the task scores could be averaged to become the complexity composite score for ANS Driving. Summation and average functions are all embedded in the corresponding cells in the spreadsheet so that the individual scores are processed automatically after their entrance from the evaluator.

The other two axes use essentially the same process. The summary sheet shows all the scores from the three axes.

LSI recommended that the guidelines for task decomposition should be as standardized as possible, since there could be many ways to do it. Hui H. briefly described how it is done in 4D/RCS [1, 2, 3]. An arrangement has been made to have Tony Barbera of NIST to give a detailed presentation on the task decomposition methodology.

LSI also recommended that the guidelines for assigning weights to and for scoring the metrics should be made as specific as possible. These three metrics development subgroup are urged to document the guidelines and integrate to the tool. A schedule will be separately distributed. The target is to show version 2 of the tool, containing these features, in ALFUS Workshop #8.

**Addition discussions on the detailed model**

It was suggested that the HRI group might look into whether the NASA SMART project autonomy levels, based on the Sheridan model, could serve as a metric on the HRI axis.

### *2.2. Summary/Executive Model*

#### 2.2.1. Benefits

Dave suggested that there isn't really a tool that is available for combat developers. The ALFUS summary model could serve the purposes. The model could help drawing either thumb-nail sketches or conclusive charts on the requirements of the targeted UMS.

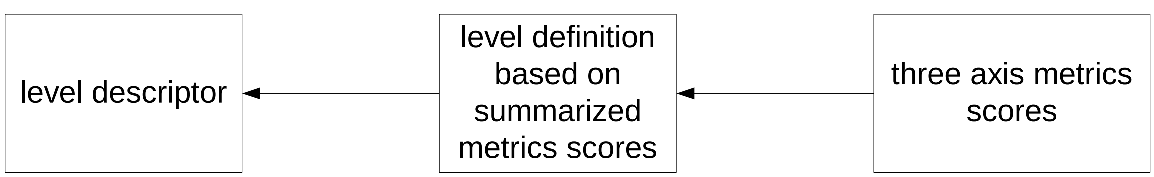
The combat developers work on the capabilities as opposed to solutions. For example, they would state requiring road following as opposed to lane marking detection system.

It is also interesting to note that the ALFUS model seems to map well with the procurement risk levels. In the FCS autonomy level chart, the low autonomy levels were marked as low risk, mid autonomy levels as mid risk, and the high autonomy levels marked as high risk. Higher risks correspond to more complex missions, more difficult environment, and less HRI. A high level PM could use the risk indications to allocate funding. This is an additional feature to the ALFUS summary model.

Bob S. commented that he liked the fact that the model could be used as a ruler, as opposed to a number.

#### 2.2.2. Approach

The following approach would be used to develop the summary (or executive) model for ALFUS:




Additionally:

- These autonomy level definitions are based on the metrics, although we do reference existent work.
- For particular levels, the metric measures/scores could probably be given as ranges as opposed to explicit numbers.

- We plan to define the lowest and the highest levels of autonomy first to scope the spectrum. We would, then, attempt to identify the middle of the spectrum for defining the ALFUS autonomy level 5.
- We will look into whether there might be key attributes for the definitions of certain levels. Remote control is an example. Section 2.2.5 contains further discussions on this.

### 2.2.3. Lowest Level

1. Defined by Remote Control (RC)

We reviewed the major existent autonomy charts and found out that they all define the lowest level as Remote Control (RC). In the ALFUS framework, remote control is addressed by the HRI axis. The issue is, then, whether mission complexity (MC) and environmental difficulty (ED), i.e., performing a very complex mission in a very difficult environment using RC would add any autonomy level to the vehicle. The participants concluded negatively. In other words, remote control defines the lowest level of autonomy. At this level, the weights on MC and ED are zero.

However, by following the explanation given in paragraph 2 below, users really have the option of using level 1 as the lowest level of autonomy to reflect the MC or ED concerns.

2. Level 0 or 1

We decided that either could be used as the lowest level. RC, as strictly defined, calls for direct control of the actuators. However, in more general situations, some of the RC might have certain levels of control logic and/or sensing built in. Some of these RC might also not directly control the actuators.

Further, typical deployed RC UMS may have employed safety features, which might be considered an autonomy feature.

Given these variations, we, therefore, concluded that users could have this option.

Another reason for us to reach this conclusion would be culture. Users or developers might feel that RC itself is a significant enough accomplishment toward autonomy (by leaving drivers off the vehicles).

There is also a suggestion to use level 1 in the summary model and 0 in the detailed model. However, the inconsistency issue needs to be solved first.

3. Current draft definition:

   *Remote control of UMS wherein the human operator, without benefit of video or other sensory feedback, directly controls the actuators of the **UMS** on a continuous basis, from off the vehicle and via a tethered or radio linked control device using visual line-of-sight cues* [4].

### 2.2.4. Highest Level

The current draft ALFUS model describes that the highest autonomy level should involve no HRI. However, in DoD, the culture is such that, the user community expects some low level HRI (about 5% to 10%) for the highest level of autonomy, whereas the research community may still seek zero HRI. UCAR was given as an example.

This demonstrated that the metric measures at a level should be assigned ranges instead of explicit numbers. At this level, the HRI could be 0 – 10%. This guideline requires further investigation.

The current draft definition is:

> *Collaborative planning to complete all required missions; understands and adjusts to the broadest scope of environmental and operational changes and information; approaching total independence from operator input.*

Some of the current autonomy charts explicitly state that the UMS with the highest level of autonomy should have human level performance. ALFUS agrees with such assessment. At this level, the sensing functions should also be self planned. The situation awareness and the common operating picture should be integrated and should be a part of the onboard knowledge base that is updated in real time to support dynamic and collaborative planning.

A question was raised as whether an autonomy level 10 UMS should be totally information independent or should have a knowledge based shared among the team and, therefore, would be information integrated as opposed to independent.

Another question along the same line is, if a team is at the autonomy level 10, does it or does it not mean that all UMSs in the team is at level 10?

Yet another question is that, in some human-UMS teams, human may be instructed by a UMS on what to do. The human becomes, therefore, a part of the autonomous team. Does this lower the autonomy level of the mixed team?

### 2.2.5. Mid Levels

The current draft definition for level 5 is:

> *Executes tasks to complete an operator specified mission; limited understanding and response to environmental and operational changes and information; relies on some operator input.*

1. Defining characteristics?

It was suggested that collaboration is not required until level 7. This needs to be backed up by the metrics and requires further investigation. In fact, to be able to collaborate on simple tasks may not require as high autonomous capability than to perform complex tasks for individual UMSs. This argues against using collaboration as a defining characteristic for the autonomy levels.

2. Mission complexity and autonomy levels
The decon example that Dave presented provided a good illustration. At mid autonomy levels, the robot might only understand its tasks of scanning the object but not what for, whereas at a higher level, the robot may understand its mission of decon and plan for the scanning as well as other collaborative tasks.

### 2.2.6. Current Status

The initial result is shown in a separate file. We drafted definitions for levels 10, 0 or 1, and 5. All the interested UMS practitioners are urged to contribute to the definitions of any of the levels.

## 3. ALFUS Application Presentations

David Knichel presented his application of the ALFUS metrics to his robotic program. His need is a high level analysis for Army combat development leadership on the autonomy levels for the collaborative robotic decontamination program.

Dave analyzed the conceptual Decon operations using the three ALFUS aspects, mission complexity, environmental difficulty, and human-robot interaction. The ALFUS autonomy levels are used to clearly indicate the desired operational requirements of the Decon operations and to help refining the Joint Tactical Decontamination System (JTDS)-Light ORD.

Dave observed that applying the ALFUS model is like having a thumb-nail sketch that facilitates high level requirement discussions. The application process forces combat developers to think through the requirements. He also observed that users should refrain from designing system solutions and should focus on specifying capability requirements during the ALFUS application process. He proposed that an automated method of data input and more clear guidelines for metrics would be helpful. Dave concluded that the ALFUS model works for his project.

Bob Smith presented Autonomous Control Level (ACL) Development for Terminal Area Operations (TAO). Task decomposition for TAO was shown. The tasks were performed using a set of identified skills. It is stressed that the skills have to be able to accomplish all missions in environments with all levels of difficulty.

The ALFUS metrics were being applied. The TAO missions were analyzed with the mission complexity metrics. He found that, for TAO, the inter-UMS collaboration level may be very high, the decision branches might be low as plans are mostly sequential, and sensory-rich UAVs require less planning. Bob's team began to apply the HRI metrics to analyze the TAO. In his setup, the skills can have different performance levels. He suggested that the ALFUS HRI metrics could help analyzing the skill performance levels. The environmental difficulty metrics were also began to be applied to a targeted test environment that has very busy flight schedules and occasional mis-execution of the scheduled missions, indicating an unpredictable, dynamic environment.

Bob's ultimate objective would be mapped ALFUS and ACL charts. Establishing primitive skill sets for various particular operation domains might be a good idea.

## 3. Administrative Issues

### *4.1. New members for the metrics development groups*

Steve S. to ED, Tom A. to MC, and Dave K. to HRI. Thanks for volunteering.

### *4.2. Next workshop*

Planned to be held within the last two weeks of January 2005 at NIST. The dates will be determined later. NIST should be ready to demonstrate advanced autonomous driving capability, then.

References:

[1] J. Albus, et al., 4D/RCS: A Reference Model Architecture For Unmanned Vehicle Systems, Version 2.0, NISTIR 6910, Gaithersburg, MD, 2002.
[2] H. Huang, "Task Decomposition Design Guidelines for the 4D/RCS Reference Model Architecture," Draft Report.
[3] A. Barbera, "How Task Analysis Can Be Used to Derive and Organize the Knowledge For the Control of Autonomous Vehicles,"
[4] "ALFUS WORKSHOP #7, The Summary/Executive Model," Workshop Slides.