ROBOT SPACECRAFT SURVIVABILITY USING A DECISION TREE FOR DATA PROCESSING

A. M. Chande
University of Maryland
Microsystems Lab
Electrical Engineering Dept.
College Park, MD 20742
(301) 454 6869

R. W. Newcomb
University of Maryland
Microsystems Lab
Electrical Engineering Dept.
College Park, MD 20742
(301) 454 6869

Abstract

This paper deals with the survivability of robot spacecraft in hostile and congested space environments. Outlined herein is a bottom-up tree that makes navigational and stability decisions and generates a sequence of control actuations for accurate trajectories for the robot spacecraft. The approach provides the spacecraft with a sense of survivability by virtue of its tactual abilities.

A path towards creating an intelligent machine and associated processing regarding its surroundings is recommended. The decision-based strategy using knowledge based heuristics is introduced to achieve autonomous and/or human assisted trajectory determination and collision avoidance, making the robot spacecraft rugged for transits in complex environments.

Introduction

With the proliferation of geosynchronous, orbital and deep space traffic, precise navigation is imperitive and present spacecraft aids are subject to errors. The true realization of the execution of decision-making, as given in the following sections, is embodied in a novel systems engineering approach described here that will provide the spacecraft a sense of survivability by means of a tactile sense-datum.

Taction for Spacecraft Survivability: Hardware Infrastructure

Intelligence cannot be wholly implemented by pushing software beyond its limits. That missing link is the hardware infrastructure that is needed for the sensory modalities, this being needed before any more software could enhance existing intelligent processing. Charles Babbage's engine was too far ahead of his times. If a systems analyst of today had travelled back in time, he could have added the much needed software component to Babbage's hardware.

The spacecraft tactile sensor architecture to be considered here, is shown in figure 1. The spacecraft should have two layers of tactile sensors, namely the aerosurface layer and the internal layer. A third layer comprises these two layers and a lattice structure linking all the sensors, aids in kinesthesia-like spatial positioning of spacecraft subparts such as the manipulator arm. The third layer also serves as a means to determine spacecraft vibrations and destability and, thus, allows for navigating to safer trajectories. Each sensor must be equipped to perform the following transductions:

1. Pressure detection (submodalities - contact, slip, prehension)
2. Temperature detection
3. Pain detection - damage assessment detection
4. Stimulus feature detection (texture, etc.)

Different types of sensors should be located in each region of the spacecraft. The outer layer of aerosurface sensors are to be protected by retractable shields during burn-ins. The three layers have specific functionalities:

1. Aerosurface sensors - These report damage assessment to external regions and surface of the spacecraft at a required resolution level. This constitutes a central perceptive layer.
2. Internal sensors - these are for functions internal to the spacecraft such as alarms and warnings for erroneous handling of controls or malfunctions.
3. Spatial composition of sensors - the combination of Sensors from both layers are interconnected by a structural lattice linkage and together they provide a sense of position and kinematic pose positions of spacecraft subparts like the robot arm.

The sensors must further be able to discrimi-

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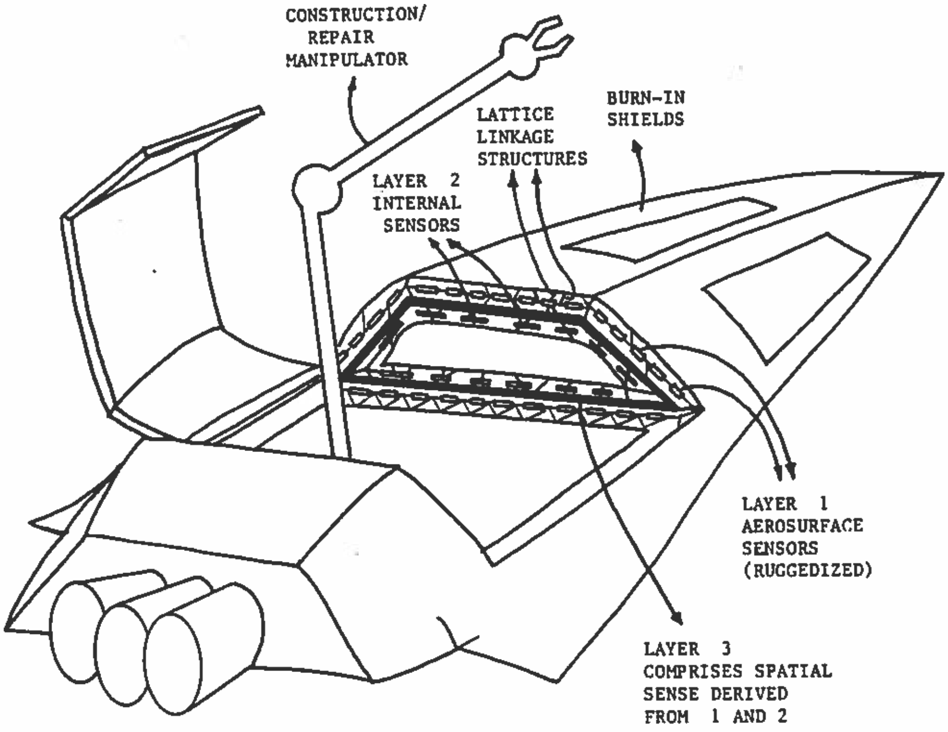

Figure 1. Tactile Architectonic Spacecraft

nate between stimuli, by pooling relevant sense-data of other sensors in their proximity.

Further the sensors should be able to detect changes in intensity of the stimulus after dicrimination is complete, by increasing either amplitude or frequency of the incomming sense-data [1]. These sensors will be superior to the functionality of their corresponding human counterparts, primarily because they will always be accurate and not subjective and also because they will sense both static and dynamic data unlike only rapidly varying data sensed by human taction [2]. Research efforts are being conducted at various laboratories in the nation and though, "In the world of robotic sensing, vision continues to receive the lion's share of research and development" [3], there are some novel tactile sensors for sale on the market. There is a growing awareness of the importance of tactual flexibility for the automated factories of the future.

The Decision Tree

The previous section describes a tactually architectonic spacecraft and the details of the sensory infrastructure needed for machine autonomy. The tree detailed here provides a decision structure for execution by the Machine Information Processor (MIP), based on spacecraft status determined from incomming sense-data from the tactual section of the Human Machine Interface (HMI), as discussed in the next two sections. Provided that there are no human overrides or interrupts, the machine is aware of its position with respect to the earth or a chosen datum, and any change in spacecraft status activates the decision tree to calculate the optimal trajectory precoded by the heuristics H. This is a dynamic process and will be in activation continuously, altering trajectories in a permissible way, and determining the spin stabilization or the three axis stabilization required by the new trajectory. The decision paths in the tree are determined by

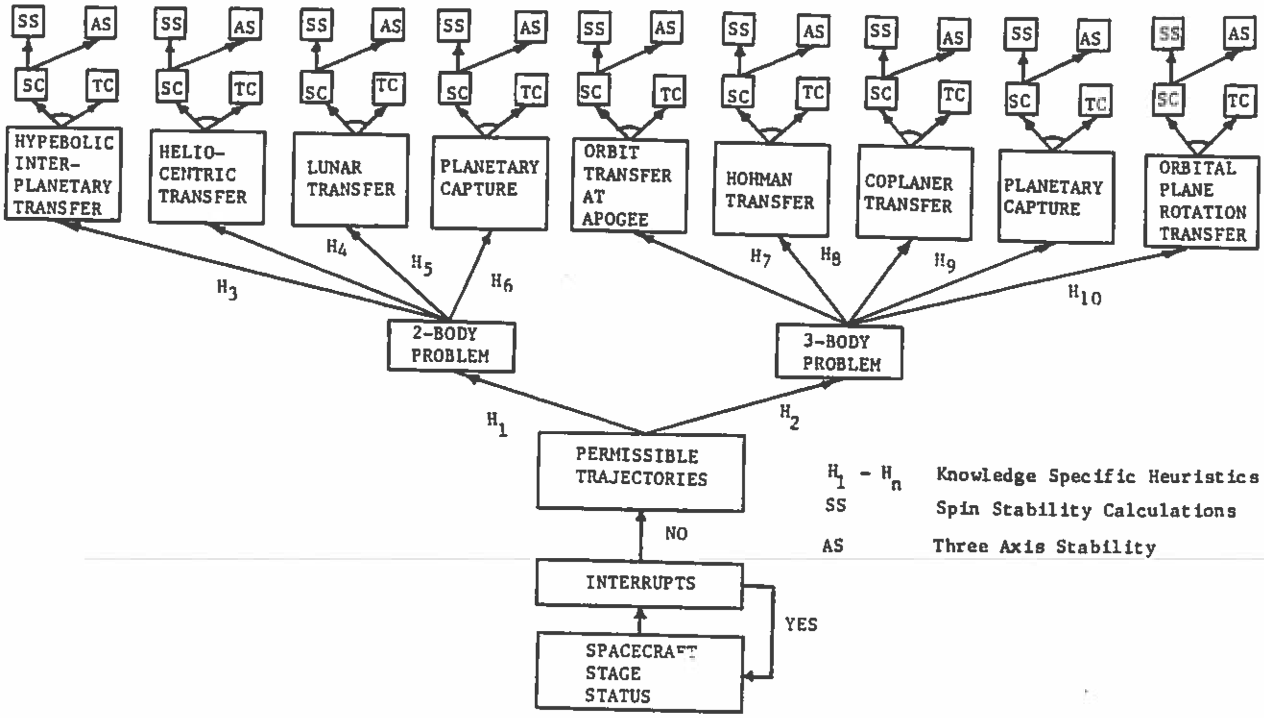

Figure 2. Decision Tree for Trajectory Determination.

knowledge-based heuristic specifics, in the relevent context, and the tree allows for the option of human updating and overriding. To prevent calamities due to decision malfunction, manual override can be activated to preserve a human problem-solving flexibility to the on-board dynamic and real-time decision maker. In addition, the trajectory calculations determine the required rigid or constant bias of momentum precession.

The bottom-up tree, shown in figure 2, depicts the structure for trajectory decision making depending on whether it is a two or three body problem and depending on the current stage of spacecraft status as given below:

1. Launch pad - idle stage
2. Blast-off
3. Booster staging
4. Orbit burn
5. On orbit
6. Re-orbit burn
7. Entry and/or re-capture
8. Land - back to idle stage after landing.

Further, the sequence of the above stages when slightly altered can result in other scenarios such as those given below for a two body problem:

1. Abort and Return to pad, after stage 3 above
2. Once-around abort and Forced Land, after 3 above
3. Transfer orbit, Re-orbit burn and Planetary capture, after stage 5 above
4. Transfer orbit, Re-orbit burn and Planetary capture and transfer orbit again, after stage 5 above and more.

The tree is to actively be used in the calculations for on-board trajectory determination at the current stage enabling a transition to a subsequent stage, provided that there is no manual interrupt. At each calculation iteration the current stage is obtained by analysis of sense-data and sense-datum difference, thus determining if it is a two or three body problem. After that depending on astro-parameters (from systems like the Primary Avionics Software System - PASS - aboard the shuttle, for example), the safest trajectory is chosen depending on branching heuristics H. After trajectory selection, trajectory path calculations, deployment parameters, and stability calculations are performed for spin stability or three axis stability. The scheduling executive program that activates this decision calculation based on sense inputs from the HMI, is the resident system software of the Central Machine Information Processor shown in Figure 4.

Towards a Truely Intelligent HMI

Sensing is not enough; relating sensed observations to associative processing task enables the understanding of reality.

The first step towards duplicating intelligent processing, which is machine resident, is when a highly correlated sensory transducing interface is built into computing machines; see figure 4, for a block diagram of a comprehensive HMI and Machine Information Processor.

The Sensory perception is achieved by amalgamating programming tools (as in or via expert Systems) for each of the three main senses (namely Sight, Sound, and Touch) in parallel, within an Expert Environment that constitutes the Pre-processing Constrained Idle Cerebro-Machine (PCICM). This portion of the machine constitutes the basis of the complete HMI. This interface may draw upon past sense-data from the memory directly or via the supervision of the Knowledge Engine (KE). The KE is a need based processor. The heuristics base, Sense-data Memory and the KE contribute to the Higher Level Knowledge Constructs (HLKC) processing. The entire process is overseen by the Self Cogitator (SC), that contributes primarily to the awareness of the entire process and the need to do so. The SC pipelines in and out at critical junctures, when necessary, based on needs assimilated from experience apart from ingrained needs.

Thus, sensory interaction when unified provides perception and association within the extrapersonal space, see Figure 5. This preprocessing is of great utility for further intelligent reprocessing. It is evident from this discussion that until we begin developing highly integrated sensory interfaces for our machines, intelligent processing may be dwarfed by our contemporary methods of independent sense perception, for lack of quantity and quality of intersensory information, resulting in ambiguities and applicabilities to specific tasks only.

Sensory Boundaries for Automated Spacecraft

Afferent neural information in humans is coded in the form of sensations (coded electrical signals varying in frequency and population) of;

1. Sight
2. Sound
3. Smell
4. Taste
5. Touch

Each of these has further sensory modalities. For the sake of simplicity and our application, we consider the senses of smell and taste as specialized forms of the sense of touch. By self-tactile perception we determine our surface volume and boundaries - this is the genesis of the ego syndrome. "'I can feel myself and having thus determined my boundaries, I am a separate entity in the environment that surrounds me.'" If someone else were to feel you, you are still aware of yourself, being touched by someone else. The whole story begins here; without the tactile infrastructure, 'knowing' is meaningless and knowledge is meaningless to the machine.

By introducing this sensory modality of datum-boundary determination, we will have given the machine a deterministic boundary - the sense-datum for itself.

Every other millimeter on our body has tactile receptors, and within this well defined boundary the noncontact senses of sight and sound aid our perception of observed reality. Therefore, for our purposes the most important sense is that of touch. The sense of touch appears to be an interface to all other senses, see Figure 3, in a modal sense that provides concommitant sense-evaluate-act motor activity for subsequent sensory investigation, see Figure 6. The sense of touch is also an interface to the physical reality that lies outside us, in a physical way. It is interesting to note that when all the portions of our body are mapped onto the cortex, the representation for the mouth, tongue and forefinger is the largest in terms of cortex regions, as compared with all other parts of our body [4].

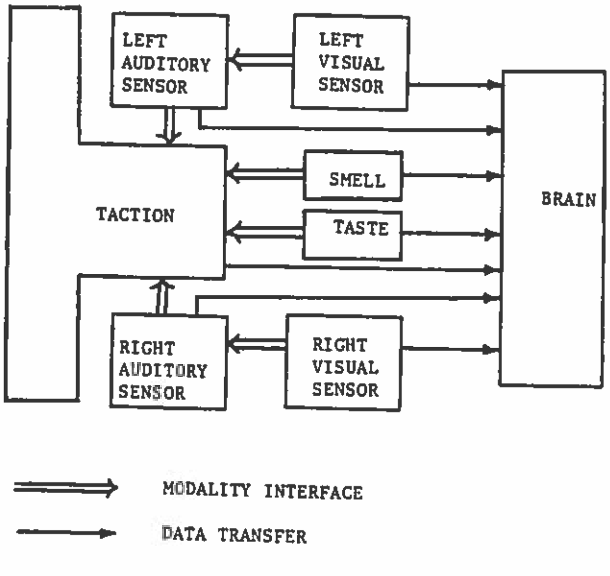

Figure 3. Touch as an Entrenched Interface to other Sensory Modalities.

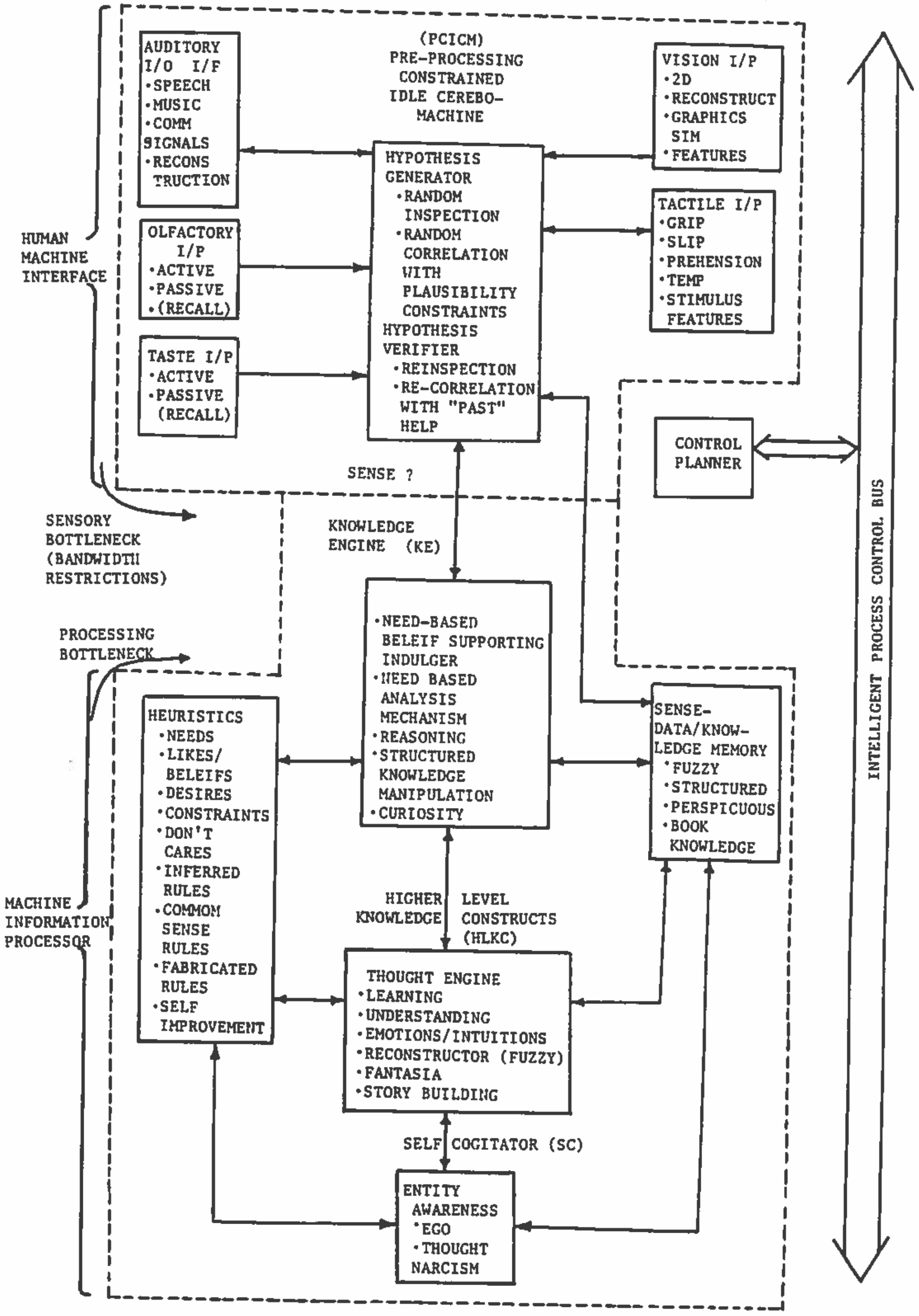

Figure 4. Towards a Truely Intelligent Machine.

In humans, the tactile interface modality is critical to the following functions of interest to spacecraft survivability:

1. Self maintenance
2. Means to construct shelters, tools, conveniences etc.,
3. In concommitance with vision and sound humans are able to understand vibrational motion.

The ability to interpret 3-D information from a 2-D retinal image (a perspective image due to visual spectroscopy and retinal curvature) is an improtant perceptive process thus, we would like to examine it here. The ability to interpret 3-D information from a 2-D image is only feasible with tactile processing and tactile abilities with surfaces. Subsequently, fuzzy reconstruction of a 3-D image with the help of visual and tactile knowledge leads to the successful interpretation of a 2-D representative perspective image. This process can be explained further - if an infant has never held a cubical object and never seen it in its hand, it may not be able to recognize a 2-D picture in different perspective views as being associated to the solid cube's representation; see Figure 5, where the object is not easily comprehendable. The ability to reconstruct fuzzy images is exemplified by a cartoonist's impression in a caricature where selected features of prominence are accentuated. The image reconstruction process in humans seems to be a regurgitation or recreation of a sensation, similar to the one received as sense-data [1] when the image was originally perceived or last perceived.

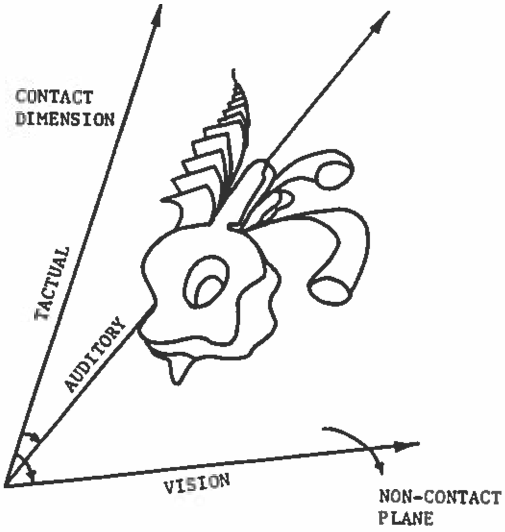

Figure 5. Perception - Associative Sensory Integration.

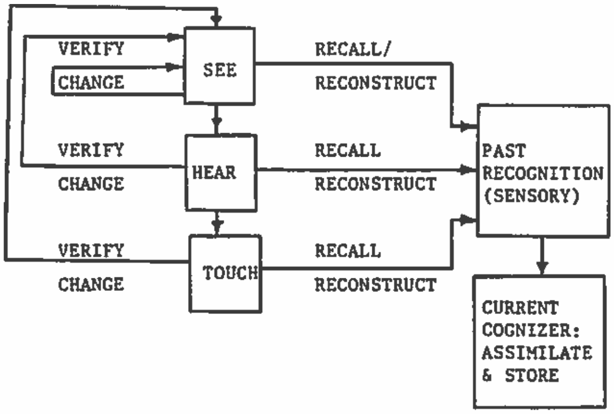

Figure 6. Sense & Re-sense Process Schematic.

R&D: Need to Stress on Intelligence Duplication

Spaced-based automation will need the development of systems capable of real-time intelligent robotic functionalities.

Intelligence, which is potential, a capacity or an ability to perform complex and involved processes, must be duplicated in all its respects, for it to be true intelligence.

We would like to emphasize that the desired end results of Artificial intelligence techniques though made by humans, are not contrived feigned or substitutes of some kind. The intelligence thus developed should be genuine or Real. It would be a lot more appropriate to look upon AI as a field of Intelligence Duplication (ID).

The current lack of direction in AI research is disconcerting and some pertinent aspects of this problem have been pointed out by respected consultants [5]. Are we trying to solve too many problems, all at the same time? For the past thirty years not only has there been no significant breakthrough in AI, but no single definition is unanimously accepted, as yet. The Standard Dictionary of Computers and Information Processing [6] of 1969, still conveys the most lucid definition as "The capability of a device to perform functions that are normally associated with human intelligence such as reasoning, learning, and self improvement. It includes...... other forms of perception and identification, artificial learning and the study of self-organizing, self adaptive, self repairing..."

Nevertheless, AI techniques applied to Natural Language (NL) processing have made quite impressive advances. As rightfully stated by Ogden and Richards [7, p.234], "The influence of language upon thought is of the utmost importance. Symbolism is the study of this influence, which is as powerful in connection with everyday life as in the most abtruse speculation."

Thoughts coded in symbols can be inspected by others and interpreted or misinterpreted in the context of their intelligence mechanisms. What is that intelligence? It is that intelligence, that ingeniously creates a mode of communication by virtue of complex skills in verbal orchestration, that utilizes this mode further to cognize and discuss the attributes of itself and lastly, that which tries to instill this intelligent ability into a servile machine to enable us to have more intelligence. Intelligence when recursively applied, results merely into more intelligence.

However, in NL the meanings associated to symbols or symbolic strings can have peculiarities, viz this meaning is variable and changes if,

1. the context changes
2. the association changes
3. the environment changes
4. the age changes (eg. 1880 or 2010)

Hence intelligence should be independent of language and symbols even though it is able to express thoughts and ideas in terms of symbols, just like the early compilers made computer programming languages machine independent. This does not preclude the use of symbols to achieve this independence. Since language, which is a communicative manifestation of thought processes conveyed when spoken and frozen when written, is an important means of transducing knowledge intelligently. Pre-learning and learning can be catalyzed by the use of language. The importance of language will be immense after the development of a completely sensory Human Machine Interface (HMI), as detailed in the previous section.

The drawback of language leads to ambiguities, as forcefully pointed out by Bertrand Russell [8] in the following quote. However, the ambiguity is overshadowed by the power it gives us in understanding abstractions, "Naive realism leads to physics, and physics, if true, shows that naive realism is false. Therefore, naive realism, if true, is false: therefore it is false."

However, symbols can be looked upon as static operators, discreticized in the time domain and serving a limited purpose individually. Proper concatenation of these static operators, based on conventional grammatical rules, generates a pre-assigned referrent meaning embodied in the string as it is in a thought. The dynamic scanning of these symbols activates the intelligence mechanism.

Endless vistas for human prosperity

"Automating much of the ground support equipment of any space station could be begun now, and could be a source of some cost reduction...."

> The Space Station
> An Idea Whose Time Has Come
> - T.R. Simpson [9, p.84]

Scientific experimentation and space-produced super materials can transform every facet of our future. We must plan ever more carefully and engineer our space systems for maximum survivability, in view of their astronomical costs and delayed replacability.

Space Stations in geosynchrony and, later in deep space will have to deal with the additional Space Traffic Control (STC) task which will make the individual control of mission-based spacecraft a severe burden. Construction and repair in space will need an immense mission monitoring overhead. Proximal trajectories for passing satellites and spacecraft will need automated on-board stability adjustment to deal with path perturbations. Furthermore, the incorporation of collision avoidance, advanced weapons, or anti-satellite systems will need trajectory automation for vehicular detumbling and incliniation control in additon to rigid or constant bias of momentum precession.

With advances in materials produced in space, the 6 million Dollar man and androidics will not be too far away in time.

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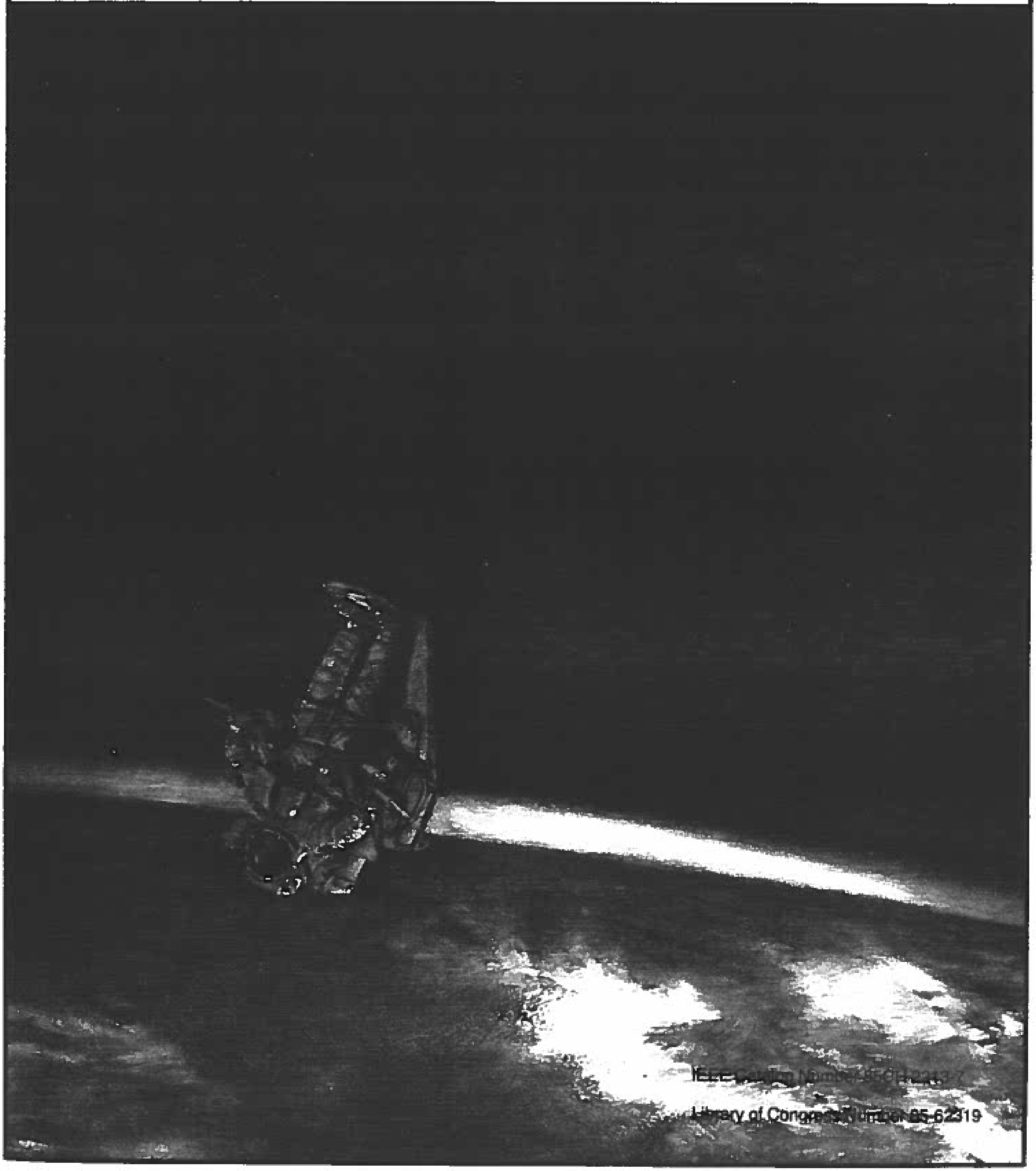

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