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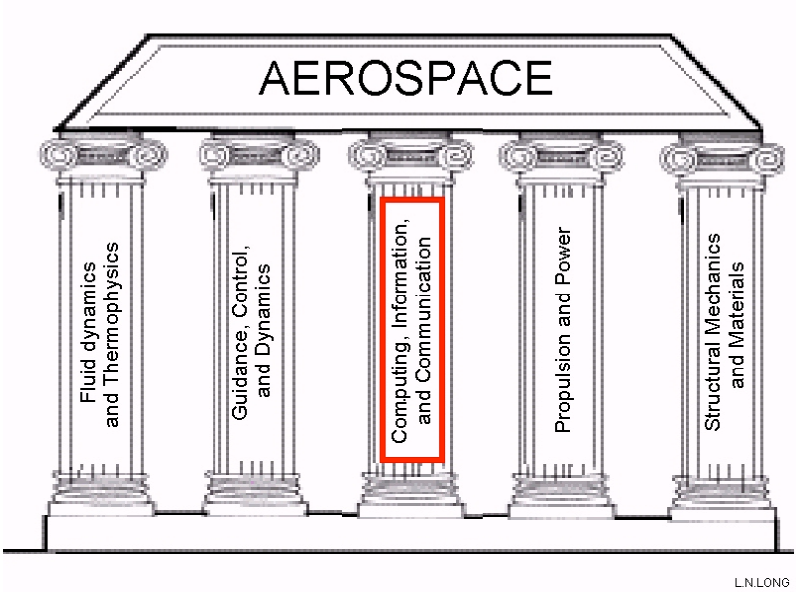
Computing, Information, and Communication: The Fifth Pillar of Aerospace Engineering

Introduction

Computing, information, and communication has become an integral part of aerospace engineering. It is now one of the key disciplines in aerospace engineering. Traditionally, aerospace engineering has been built on four "pillars": aerodynamics, propulsion, structures, and dynamics/control. These pillars are reflected in aerospace engineering curricula, the management structure used in the aerospace industry, and the index categories used by AIAA to classify papers. All of these disciplines were important for the Wright Flyer and for every aerospace system since then. These four disciplines have historically been well served by the six existing AIAA journals, but there is an enormous amount of work going on in aerospace that does not fit within the scope of these existing journals. However, modern aerospace engineering must include five pillars. Future aerospace systems will be designed using computers, they will have computers onboard, and they will need to communicate with other vehicles and other computers. Computing, information, and communication are key parts of aerospace engineering: CIC is a fifth pillar.



There are numerous examples that illustrate the importance of CIC in aerospace. For example, the Boeing 777 has more than 1000 onboard processors that use more than 4 million lines of software. The F/A-22 Raptor has 2 million lines of software onboard. Some Blackhawk helicopters have almost 2000 lb of wire connecting all the computers and sensors. There are aircraft that cannot fly without their onboard computers. Autonomous intelligent unmanned vehicles will be very important in the future, and will obviously require sophisticated onboard computers, software, and algorithms. Computers are also important in the design and analysis of aerospace systems, from simulations of the turbulent flow over wings to predictions of the orbital mechanics of spacecraft. Communication systems are critically important for aircraft and spacecraft, and this now includes computer networking onboard, to the ground, and to other aerospace vehicles. In addition, high performance parallel computers can now sustain more than 30 trillion calculations per second, which allows detailed analysis and design of complex aerospace systems.

The *Journal of Aerospace Computing, Information, and Communication* (*JACIC*) is an exciting new venture for AIAA and is an indication of the importance of digital systems. This new journal begins publication in January 2004, and is devoted to the applied science and engineering of aerospace computing, information, and communication. The term information technology (IT) is widely used, but it is not usually interpreted to include all the diverse topics covered by *JACIC*.

This journal includes letters, papers, invited papers, book reviews, and other articles. All articles are reviewed electronically to allow for rapid dissemination. There are currently 14 Associate Editors, and their biographies are available on the journal's Web site. The journal is electronic (online) and published "continuously." It also includes multimedia content. The paper submission and review process is completely online, with no need for paper copies. This is accomplished using AIAA's online submission and tracking system, WriteTrack™.

JACIC expands AIAA's activities in aerospace-related information technology and multimedia publishing. Technical journals no longer need to be limited to text-based publications, and Web technology also allows online discussions. The *JACIC* Editorial Board hopes to allow as many multimedia file formats as possible. At this time, the following formats are accepted: wmv, xls, doc, ppt, mdb, html, gif, jpeg, mov, pdf, txt, zip, wav, and mp3.

Multimedia documents are crucial for the efficient transfer of knowledge. The fantastic and informative multimedia presentations that are seen at conferences can easily be included in a multimedia online journal. Animations, audio files, and even stereographic images can be hypertext-linked in multimedia documents. Also, when data are presented graphically, a link can be included to a file containing the original data (to any precision). This will permit future researchers to compare their results more easily and more accurately. In addition, the encapsulation of the data does not have to be limited to simple spreadsheet files. Entire solution datasets, such as four-dimensional fluid dynamics solutions, can be included. This allows the reader to post-process the data in any manner they choose. Microsoft® PowerPoint files from conference presentations can be attached as well. In fact, entire computer programs can be included, and these programs could become part of the archive. Collections of files can be zipped as well, so that complex collections of files and directories can be attached. To encourage the effective use of multimedia documents in *JACIC*, we will recognize the best multimedia papers of the previous year each January.

JACIC Scope

Computing, information, and communication can be viewed as three axes of computer science. If we define information in a very general manner (e.g., data, maps, images, audio), then computing involves processing or creating information, and communication refers to transporting the information. *JACIC* will include papers in all areas of CIC relevant to aerospace systems: real-time systems, computational techniques, embedded systems, communication systems, avionics, networking, software engineering, software reliability, systems engineering, signal processing, data fusion, computer architecture, high-performance computing, computational science and engineering, expert systems, sensor systems, intelligent systems, and human-computer interfaces. The scope of the journal is expected to evolve as technology evolves. Articles are sought which demonstrate the application of recent research in computing, information, and communications technology to a wide range of aerospace engineering problems.

Digital Format

Archival journals represent one of the cornerstones of technology. The historical record of engineering and scientific progress is documented in thousands of libraries containing volumes from ancient to modern. Many of these journals originated in a very different age. Today there is instant worldwide communication, and information can be distributed at the click of a button. Printed journals are costly to produce, distribute, and store. Even the definition of an archive is changing. A shelf full of books is really no more permanent than the same information on a CD-ROM or a hard drive, and it takes up a great deal more space. Tragedies, such as fires, can easily destroy entire libraries, such as the Library of Alexandria. With the worldwide Web growing exponentially, the usage of old dusty volumes will be dwarfed compared to the exchange of information that occurs on the Web. In the future, information that is not online will be used less and referenced less.

Digital archives will create some new problems as well. Paper-based documents appear the same, even after thousands of years. This is not necessarily true of digital documents, which might appear differently when different software is used to view them. This is true of virtually all the formats used today. It will be important to ensure that the electronic documents created today will appear the same thousands of years from now.

Another problem is the lack of permanent uniform resource locators (URL) (Ref. 1). It would be useful to include hypertext links in documents, but the URLs can change so often that they cannot be used in archival documents. Online information is growing exponentially but the ability to manage and maintain it is not keeping up with the pace of change. If you try to imagine which current URLs might be valid in 100 years, it is likely to be a fairly small subset of present day URLs. Of course, this assumes that the naming convention will remain the same. There are few organizations or corporations that can be guaranteed to exist in 100 years, but science and engineering archives must be preserved.

AIAA (along with other professional societies) is rapidly changing its mode of operation. Conference papers are now available both online and on CD-ROM. In fact, AIAA is in the process of a massive operation to digitize their entire collection, including all their conference papers ever written and all their journal papers. Once this collection is online and searchable, its value and usage will increase dramatically. NASA is also digitizing much of its collection of technical papers,* including NACA reports. The Library Congress is concerned about digital preservation as well.†

Because paper-based journal publications are expensive to produce and distribute, strict page limits are usually enforced. The details of the research are often left out. Today there is much less of a need to limit the length of papers. Does it still make sense to summarize a Ph.D. dissertation in a few short papers, and refer to the Ph.D. thesis for the details? Entire collections of Ph.D. theses are now available online,‡ and are sometimes easier to find than archival papers. In addition, the printed word is a very limiting format. There is no reason not to include graphics, animations, software, audio files, and databases, and link them to the papers. Communication between the authors and the readers can also be facilitated, as discussed next.

Online Communities

The traditional role of a journal is in information retention and distribution. Also, the manuscripts are validated through careful refereeing by acknowledged experts. But information is not knowledge. Knowledge "is a fluid mix of framed experience, values, contextual information, and expert insight that provides a framework for evaluating and incorporating new experiences and information".[2] Hundreds of years ago, the authors and readers of prestigious journals, such as those of the Royal Society, were a small community of scholars. The journals allowed them to share information, but in a slow and expensive manner. Today, using modern Web-based software, it is possible to set up very powerful online communities.[3,4]

Online communities go far beyond traditional newsgroups and chat rooms. Modern online communities (often called communities of practice or communities of interest) include features that were not possible 10 years ago due to the state of software, algorithms, and networks at that time. Some of the features available with today's online communities are

1) document and information management system,
2) search engine,
3) online contact information (business cards) for users,
4) regular face-to-face meetings,
5) user registration and login,
6) calendar of events,
7) community building software (the community builds the Website),
8) taxonomy, classification, and indexing of information,
9) simultaneous (real time) collaboration and information sharing,
10) news and threaded discussion groups (one of oldest features), and
11) chat and instant messaging

The first six items are already contained in the AIAA Web site, which is best described as a portal, not a community of practice. It is quite easy to also incorporate discussion forums, but to do this correctly it must be a well-designed database system coupled with good community building software. An excellent example of software of this sort is Simplify™, developed by Tomoye, where everything in the system is considered a "knowledge object". One of the key features of an online community is that the Web content is under the control of the community, rather than having Web masters manually edit and maintain the Web pages. Software now makes this relatively easy.

Online communities thrive through the interaction of people and the free flow of ideas. Through conversation, the community filters and validates information "on the fly".[3] Journals, however, are publications of thoroughly validated articles that have been certified as legitimate by experts in the field. The combination of a journal and an online community could create a system for validating information while allowing the community to have discussions and facilitate knowledge transfer. Technical papers usually provide information; it is very difficult to

*Papers may be found online at http://techreports.larc.nasa.gov/ltrs/ltrs.html; http://ntrs.nasa.gov; and http://naca.larc.nasa.gov (cited Jan. 2004).

†To learn more about the Library of Congress digital preservation program, please visit http://www.digitalpreservation.gov. (cited Jan. 2004.

‡Examples of Web sites containing theses are http://scholar.lib.vt.edu/theses and http://www.etda.libraries.psu.edu (cited Jan. 2004).

transfer knowledge through technical writing alone. A combined community and journal could have a multi-tiered validation system that helps convert information and tacit knowledge into explicit knowledge. Person-to-person discussions (in online communities and at conferences) are crucial for the transfer of knowledge, as are multimedia documents. As *JACIC* evolves it is planned to build an online community for everyone interested in aerospace computing, information, and communication.

Conclusions

It is a new era for aerospace systems, as well as for publishing, but this new journal and the new approaches to publishing and collaboration will take time to be accepted. It will take time for authors to learn how to present their research and development in the multimedia formats. It will also take time to learn how to build effective online communities; but digital archives and online communities will be essential in the future, because information is increasing exponentially. Archiving information is easy. It is important to go beyond that though, and implement effective knowledge-management techniques. Technology can be used to advance technology, which leads to dramatic advances in science and engineering.

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