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Paper Session I-C - COTS- Pros & Cons Associated with use in Future Launch Vehicle Avionics

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Abstract

This paper examines and discusses some of the key issues associated with the use of COTS products, systems, and technology in modern avionics and their embedded computer systems. Emphasis will be on future space projects, such as reuseable autonomous launch vehicles.

Introduction

A definitive trend toward use of *commercial-off-the-shelf* (COTS) hardware and software exists today, due essentially to the perceived front-end= and schedule

DOMINANT DRIVER ----------COST (Budget Constraints)

SECONDARY DRIVER----------SCHEDULE (Also translates into COST)

WHY COTS -----SOME INTERESTING TRENDS...

- **Commercial/Industrial sector now DRIVING technology,**
- **Unique/Custom designs & systems are costly and quickly become obsolete,**
- **Obvious advantages and benefits of commonality and standardization,**
- **Growth and evolution---Technology Insertion.**

Figure 1: The Utilization of "COTS" is Becoming a Definitive "Requirement" !

savings potentially accruable to a project. This trend is expected to continue, especially in the avionics and computer systems associated with future military and space projects, and will most likely become a definitive program *requirement*, as discussed in **Figure 1.**

Background--Some Interesting Trends

The commercial & industrial sectors are now primarily driving most innovations with new technology. Coupling this fact with 1), the issue that unique/custom designs are costly and become quickly obsolete, and with 2), the limited budget situation, program planners and project managers are forced to consider and evaluate new ways to implement future systems, As shown in **Figure 2,** the various aspects of the COTS environment seems to be one effective tool at their disposal.

MIL / AVIONIC / SPACE designs/ systems/ technology/ products are based on some aspect of a similar commercially-based item.

MANIFESTATIONS OF COTS ITEMS...

The Utilization Spectrum

Full Commercial----Industrial---- Rugged / Hardened----Military / Avionic----Space

Most Typical Hardware Uses	Most Typical Software Uses
o Rugged / Hardened Product or U nit	o Operating Systems
--a computer--best example	o Development Tools and Support
o Mil / Space version of Part or Technoloy	o Utility Software
--higher grade--screened--tested	--Compilers, Assemblers.
--more stringent mfg. Process	--Simulation, Testing.

Figure 2: What is "COTS" ?

COTS---Definition

The acronym "COTS" means *"commercial-off-the-shelf"*, but must have an additional modifier--defining WHAT is commercially available. We use the term loosely, and should actually use "COTS hardware" or "COTS software" or "COTS parts", when we use the notation.

The basic definition is given in **Figure 2,** and is in its general form, can be stated as follows:

> *Military/Avionic/Space designs/systems/technology/products are BASED on some aspect of a similar commercially available item.*

The utilization spectrum of hardness levels **(Figure 2)** spans from full commercial all the way to fill Class-S space qualification. COTS may manifest itself in any portion of the spectrum from industrial/rugged on to the right. Generally, space projects will concentrate on military/avionics levels with special cases requiring the full space level.

Typical manifestations of COTS for the hardware and software realms are shown in the table in **Figure 2,** giving the most common places where the COTS item may offer the most benefit.

COTS--Applied to Space Launch Vehicles

An understanding of what COTS *can* and *cannot* do for a project is key to a successful utilization, leading to the desired savings. For applications, operations, and functions that are flght critical, the avionics hardware products and parts will not necessarily be truly commercial grade (per se), but will be harder versions--**based upon** AND **traceable to** AND **compatible** with--their commercial counterpart or equivalent.

Generally, for space utilization, additional hardness levels are necessary for hardware technology to tolerate the unique restrictions of the space environment. The most demanding of these added hardness levels are typically:

. Wider temperature range,
. Higher shock and vibration,
. Operation in vacuum,
. Radiation tolerance.

Utilization of commercially-based software in space avionics does not have the environmental restrictions of the above hardware, but must satisfy its own unique set of requirements, such as:

. Operation without significant errors,
. Pass Verification and Validation Testing,
. Support Upgrades and Changes,
. Satisfy Reusability Requirements.

Figure 3 provides an overview of the programmatic aspects of COTS items, as applied to space launch vehicle projects--showing the most typical areas that can benefit, along with a list of things that COTS cannot generally perform.

As Applied to Space Avionics (Launch Vehicles, etc.)

COTS can...	COTS cannot...
o Lower front-end development & design costs,	o Reduce costs and schedules to zero,
o Reduce risk that technologies are valid,	o Use comm-grade parts in critical areas,
o Cut critical front-end acquisition schedules,	o Eliminate ALL unique/custom designs,
o Provide compatibility and standardization,	o Eliminate verification & validation testing,
o Support growth and technology insertion.	o Eliminate configuration control.

Figure 3: What COTS *can* and *cannot* do...

COTS Software--Discussion

The use of COTS software (S/W) will probably be the toughest, as has been already exhibited in some projects. Its use will depend on the project and its mission; how critical the application will be (for launch vehicles these critical

periods are usually during ascent/boost and reentry/landing). COTS S/W will not have the "usual" front-end requirements specification, nor will it have the back-end verification and validation assurances. These create criticism of COTS S/W and can drive the cost back up when all of the classical steps and procedures are added back. This situation presents a *trade* area for project software managers--without these added items, the RISK can go up, if the application is indeed critical--but if all of the procedures and tests are blindly included (as a matter of course), then the COST returns to its former level, and software becomes the critical item on the project schedule. It therefore, behooves software managers and engineers to carefully select their COTS, then to only append those extra tests & procedures that are deemed absolutely necessary.

Aside from the above issues related to using COTS S/W, considerable front end savings can be realized through the use of programming languages already developed and in widespread use, and similarly, through the use of operating systems and development/support environments.

COTS Hardware--Discussion

Utilization of COTS hardware (H/W) is generally somewhat more straight-forward---the commercially-based technology and/or products may be ruggedized/hardened as needed and still maintain most of their compatibility with their low-cost ground equivalent. Computers are unique in that they can still maintain their software compatibility generally independent of their packaging. The Loral Radiation-Hardened (RH-6000) 32-bit RISC processor is an excellent example of this, since it can run the same software as ground workstations, and is available in radiation-hardened space qualified versions.

On the H/W side, however, there are also factors that impact the compatibility--for computers this is usually the input-output (1/0) that must be used for the avionics application (busses such as 1553, for example, are not typically found in commercially-based ground products---but can be added in most instances, so that the ground equivalents will match the flight equipment).

Benefits of COTS to Space Avionics

The space industry, in general, will go through some challenges in attempting to use COTS---so there will be a transition period--to change procurement, development, and validation methods---and the attitude about "the way we used to do it". This will be eased somewhat in the software area by the maturity of some

commercially based products, along with their increased usage in critical highly reliable real-time applications (closer match to onboard avionics requirements).

Figure 4-A compares the classical and COTS approaches, showing the cost and schedule portions of the savings that can result from the shortened development cycle at the front-end of the project. Typically, the COTS break-in occurs at the equivalent of the prototype level, since the product or technology already exists.

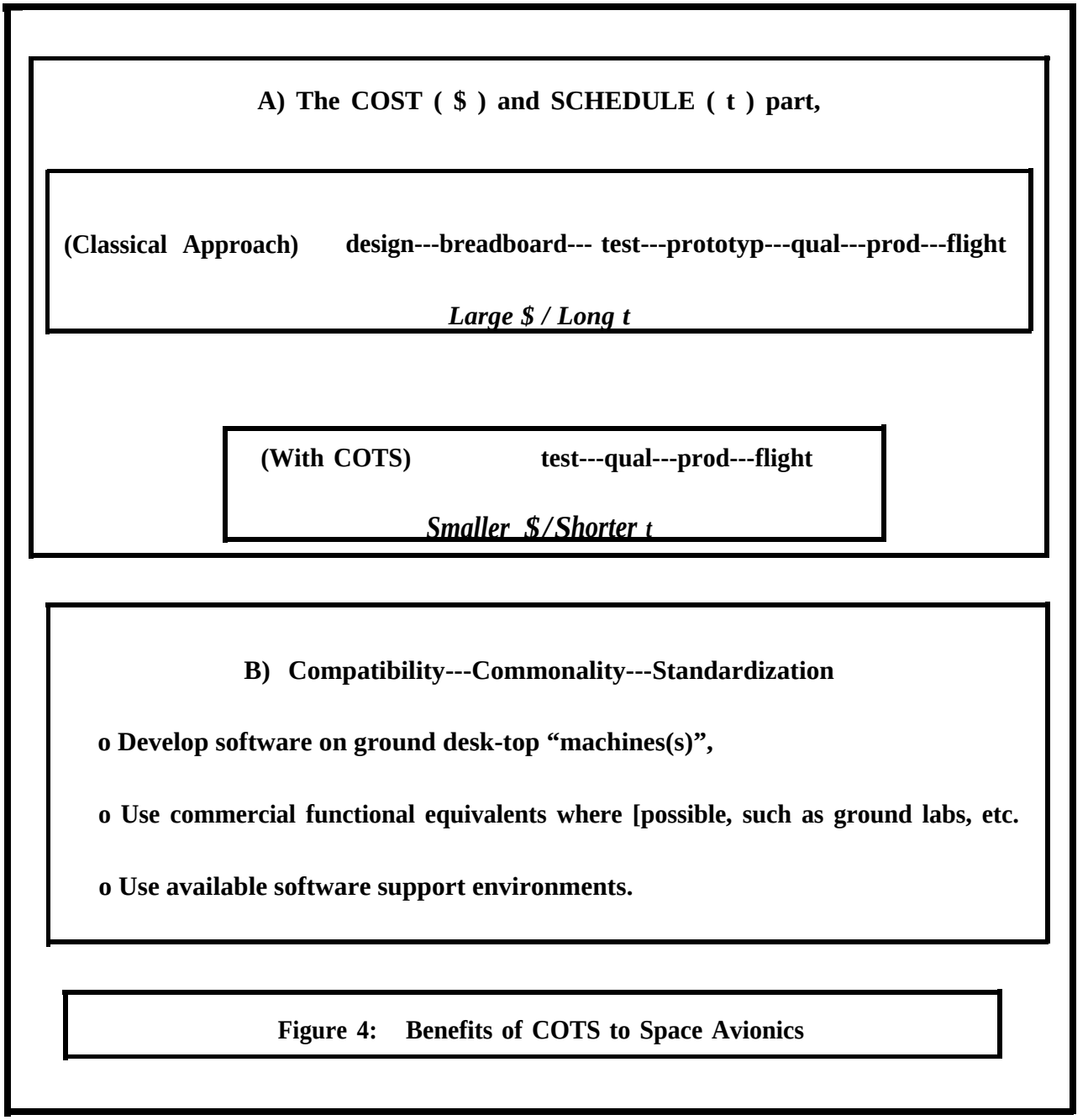

Figure 4: Benefits of COTS to Space Avionics

Figure 4-B lists some of the additional benefits available to a large project due to the flight/ground compatibility that should exist, and to the commonality and standardization that will result.

Issues Related to COTS

Utilization of COTS for space avionics is not without issues, as indicated in the sections discussing hardware and software. Some of the more pertinent of these issues are listed in Figure 5, which forms the base for the challenges to the project manager and the chief engineer.

o Versions and Product Support rapidly move to next generation (impacts long-term multiyear projects),

--must examine growth and evolution plans,

--configuration control issue,

o The commercial item "goes away"---no longer available or supported,

o Multiple Vendors---difficult except for cases where widely used industry standards have proliferated,

o Quantities for space related projects are usually small---driving cost of hardened versions,

o Software---has most of the above issues plus the following unique items...

--Real-Time multitasking OS technology for fault-tolerant systems,

--COTS NW for flight critical functions and operations,

--Autocode is emerging---remains immature for non-control applications.

Figure 5: COTS----Some Issues...

Summary and Conclusions

Most good commercial technology and products today (especially computer architectures) are planned to have growth and evolution (such as an upward-compatible "family"), which enhances the capabilities for technology insertion---vital for a multiyear long-term project, to avoid *technological obsolescence* for the processor systems at the heart of the avionics. This will be especially important for future reusable launch vehicles, since their operational life-times will extend over many years. An overview of the conclusions is given in Figure 6.

0 Can no longer *afford* to utilize unique or custom designs when commercially-based counterparts exist,

Even though COTS is not the PANACEA)

o *Education is* necessary as to what COTS actually offers as well as what it does not provide,

o COTS must be used for the right reasons---front-end cost & schedule reductions are usually critical,

o COTS hardware& software merges (overlaps) the space sector with the commercial,

(opens key benefits due to commonality, standardization, & compatibility).

COTS

The *ANSWER* to Cost& Schedule Issues Associated with

Future Long-Range Space Projects, such as Reusable Autonomous Launch Vehicles

Figure 6: COTS--Utilization in Future Space Avionics Applications--CONCLUSIONS