(U) Cost Improvement for Space Systems

(U) Introduction

This white paper contains a summary of the various approaches used in the Space Community to evaluate and quantify space hardware cost improvement. Each Agency may have a unique adaptation of cost improvement curves; however, these basic principles still apply.

(U) Definitions

Cost improvement is classically referred to as the reduction in recurring cost of satellite hardware with increasing number of units (e.g., vehicles or hardware end items). Cost improvement curves (CIC) are broader in scope than traditional learning curves, as defined in most learning curve literature. The sources of cost improvement measured by CICs may reflect, but are not limited to: 1) touch labor learning obtained through hands-on manufacturing, assembly, and test work – the scope of traditional learning curve theory; 2) non-touch labor costs (e.g., production support, setup activities, material purchases, supply chain management) spread over the total production buys; and 3) other factors.

CICs conventionally take one of two forms with respect to the underlying behavior – unit theory cost improvement and cumulative average (cum ave) theory cost improvement. In the space industry we anticipate a less than optimal production flow due to relatively small quantities, long production times, unscheduled rework, and introduction of engineering changes. For these reasons, it is widely accepted to model cost improvement using the cum ave theory.

(U) Air Force Cost Analysis Agency (AFCAA) Approach

The AFCAA has implemented a similar approach to the NRO CAAG for measuring cost improvement of space hardware, using quantity as an independent variable (QAIV) techniques. Space hardware is first grouped according to subsystems as defined in MIL-STD 881C Appendix F (Space Systems). Within each subsystem the unique cost improvement can be measured as a function of both satellite quantity and/or end item (box) quantity. Results of the analysis are included below. AFCAA and AF SMC teamed up to contract out for an independent assessment of cost improvement curves within the Department of Defense (DoD) space portfolio and the study concluded that ~90% CIC was appropriate at the spacecraft bus level.
Because each program has a slightly unique acquisition strategy, AFCAA recommends using the results above as a default position only. Cost improvement curve by analogy to a similar system or tailoring the methods to the actual terms of the subject contract may yield more realistic results. The OSD CAPE recently paved the foundation for the purchase of satellites in blocks and/or multi-year contracting using procurement funding (Air Force Appropriation 3020). These acquisition approaches offer the opportunity for industry to create commitments to the supply chain and provide for an efficient production cadence. To understand the impact block buys have on cost improvement, the AFCAA team went back into the DoD satellite database (USCM-9) and evaluated the individual lot quantities (e.g., contract line items) for each contract. The results supported the hypothesis that those systems procured in larger lot quantities experienced more cost improvement over traditional 1 or 2 satellite acquisitions. By introducing an a-priori rate curve of 95%, AFCAA can now more effectively model satellite block buys. The approach to use both a learn and rate curve is not a novel concept, in fact the method is frequently used in the Aircraft and Missiles commodity areas. Industry has taught us to expect a benefit from block buys as supply chain commitments are increased, this is the economic order quantity impact. The resultant equation takes the following form:

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Cost = T1 \times Contract\ Qty^{CIC} \times Lot\ Qty^{Rate\ Curve}
\]

In summary, the AFCAA analyses of cost improvement within DoD has produced results similar to 85/90% (Bus / Payload) used for data normalizations at the NRO. Furthermore, AFCAA expanded the analysis to incorporate a rate curve which models unique acquisition strategies.
COST IMPROVEMENT FOR MULTIPLE VEHICLE CONTRACTS

The AFCAA approach for implementing cost improvement curves in cost modeling depends on a number of unique factors such as contract / lot quantity, analogy take-off points, and production build schedules. In multiple vehicle contracts (or contracts with lot quantities exceeding the analogy take-off points) both cost improvement and rate theory is applied. Particular attention is also given to the amount of time between successive satellite builds because that may introduce “loss of learning” and create some incidental non-recurring costs.

COST IMPROVEMENT AT ELEMENT LEVEL VS TOTAL VEHICLE

Limited by the DoD data that is resident within the USCM database, AFCAA could not accurately compute reliable cost improvement curves at the component (i.e., box) level. Without detailed space hardware datasheets it is very challenging to determine the actual number of components produced on each contract, including spares and test units. The subsystem level analysis is more defensible. Rolled up to the Bus and Payload levels and then ultimately the Satellite level, AFCAA anticipates cost improvement curves will approach 90%.

AFCAA believes the CIC values computed by the NRO CAAG are reasonable when computed at the end item (i.e., box level).