Professional Development Short Course On:

Risk Assessment for Space Flight

Instructor:

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RISK ASSESSMENT AND MANAGEMENT
Summary of Course

Risk is the probability that something bad will happen and its consequences.

All of us in the aerospace business deal with this reality, constantly juggling parameters, design choices, and project decisions to get the best overall system performance at a manageable level of risk. To do that we must learn how risk arises, what its consequences are, how to mitigate it, and, finally, how to integrate into our day-to-day project management processes.

This three-day course delves into all aspects of risk management, from detailed tools and techniques to identify, analyze, mitigate, and track risks, to lessons learned from previous projects. Its basic purpose is to give you a background that will let you structure your own project risk management process. The course is supported with over two hundred pages of material and is intended for engineers, project management personnel, and technical administrators.

The scope of the course, details and typical discussion charts of each of the course's following topics is given below

- Introduction
- Methods to Identify Risk
- Risk Analysis
- Tools and Techniques
- Risk Modeling
- Software Risks
- Detail Design Issues
- Risk in COTS
- Risks in Better, Faster, Cheaper
- Examples from the Mars Programs
- Risk Tracking and Documentation
- Historical Examples
- A Detailed Case History

Introduction

We begin with basic definitions and general ideas about risk-consequence relationships and how to rank or categorize them as controlled risks, acceptable/unacceptable/catastrophic risks. Some generalized equations and their interpretations are presented. The notion of Risk Factors is introduced.

Risk

. . . . quantitative aspects

$$R = \sum_s P_s C_s$$

R = probabilistic risk assessment; Ps = probability of outcome consequence of outcomes. Simplistic example: You bet $100 coin toss, R = 0.5 x $1000 = $500.

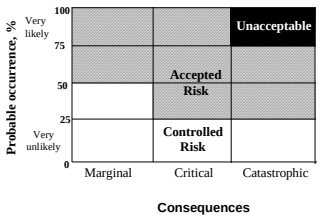
PITFALLS: If applied to missions using fault trees for the P's be mindful that:

- Fault trees can't always capture all the possible failures
- Common-cause failures (all valves have a common defec not truly independent.
- C's may vary with time.
- Many risk-related decisions are driven by perceptions, nc necessarily by the above equation. Perceptions of conseq tend to grow faster than the consequences themselves, i.e several small accidents are not perceived as strongly as o one, even if results are the same.

Background

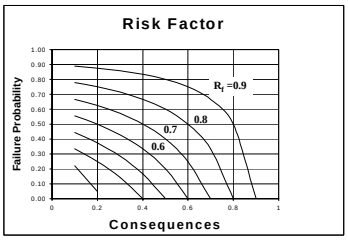
- "Risk is inherent in [all] space missions. Effective identification and management of risk are critical responsibilities of project management and often determine whether a mission will be successful."
  Mars Independent Assessment Team Summary Report, 3/14/2000.
- Government and commercial policies have changed
  - Science satellite down-sizing
  - Cost, schedule down-sizing
  - Faster, Better Cheaper
    - encourages prudent risk where justified by the return - but only if well-managed. Risk that deviates from sound principles is not acceptable.

Risk Assessment



Risk Factors

$$R_f = P_f + C_f - P_f C_f$$

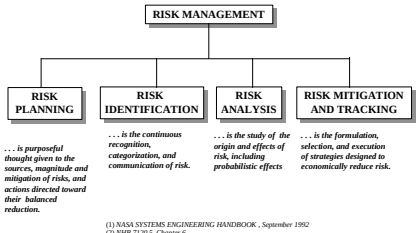


An important part of risk awareness is the culture of the management team, its prevailing attitudes about technical margins, failure realism, and redundancy/weight tradeoffs. It is discussed in the following two charts

Culture Issues in Risk Management

- ***Arouse risk awareness as a design factor***
  - ***Incentives, rewards, penalties***
- ***Prevailing attitudes regarding risk***
  - ***Technical margins***
  - ***Failure realism (what is the reaction to failure?)***
  - ***Redundancy***
- ***Risk ownership***
- ***The Faster-Better-Cheaper factor***

Risk Management



(1) *NASA SYSTEMS ENGINEERING HANDBOOK , September 1992*
(2) *NHB 7120.5, Chapter 6*

Risk Management

Risk management is the focussed, unrelenting effort to confront uncertainty and bring it into adjustment with the technical, safety, cost, and schedule goals of the project.

The measures by which we categorize risk depend not only on management attitudes but also on where the project fits into national interests. Contrast risk that may be acceptable in unmanned missions or short mission life vs those in manned missions or high national interest or high commercial value.

Risk Identification. Where to look

Risk factors lurk in all aspects of a project's development and use. Some obvious places to find them are the project's defining documents, consulting with experts, and the use of risk identification tools, e.g.:

- The contract and its Exhibits (SOW, WBS, Specs)
- Expert interviews
- Lessons Learned Data Base
- FMEA and Criticality Analysis
- Risk Templates (as in DOD 4245.7M)
- Schedule Assessment
- Technical performance margins
- Modeling, as in
    - PERT margins
    - Monte Carlo Simulations

Technical risks

Probability that the system will not attain its technical objectives, and the severity of the consequences.

- ❑ **Reaching beyond the state-of-the-practice in hardware or software performance.**
- ❑ **Unrealistic performance expectations**
- ❑ **System complexity**
- ❑ **Interfaces**
- ❑ **Requirements changes**
- ❑ **Manufacturing problems**
- ❑ **Testing / modeling**
- ❑ **Reliability / quality**
- ❑ **Parts / materials**
- ❑ **Launch and in-orbit operating environment**
- ❑ **Life and aging**

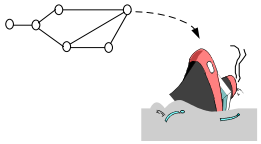
Schedule risk

Probability that the project will fail to meet its schedule objectives and the severity of the consequences.

- Coupled to technical risk
- Coupled to cost risk
- Coupled to mission operations risk

What to look for

- Estimating errors
- Number of items on critical path
- Allocated reserve. Little or none.



Programmatic risks

Probability that the mission will not reach its program objectives and the severity of the consequences

- ❑ Lack of political advocacy
- ❑ Spotty funding
- ❑ Contractor / subcontractors capability
- ❑ Personnel skills and availability
- ❑ Inter-program conflicts
- ❑ International involvement
- ❑ Requirement changes
- ❑ Organization conflicts
- ❑ Regulatory changes
- ❑ Communication problems
- ❑ Single source suppliers
- ❑ Material availability and delivery
- ❑ Environment impact
- ❑ Labor strikes
- ❑ Security
- ❑ Acts of God

Cost Risk

Probability that the project will fail to meet its cost objectives and the severity of the consequences.

- ❑ Unrealistic cost estimates. Little or no cost reserve.
- ❑ Unrecognized or unmanaged technical risks
- ❑ Unrealistic performance (system complexity) or schedule expectations
- ❑ Requirements changes and/or shifting baselines
- ❑ Inappropriate allocation of resources
- ❑ Estimating errors / labor rate changes / inflation surprises
- ❑ Programmatic or political factors

Cost risks can arise from a number of factors starting with bad estimation or unrealistic goals, whether poorly understood at the working level or enforced from above, or due to growth from the baseline, generally from other risks gone bad.

Risk Analysis… Putting numbers into the mix

Many formal methods have been developed to help identify and measure the effect of risk on decision-making. In this part of the course, we examine some of the better-known ones to determine quantitatively:

- *What can go wrong?*
- *How likely is it?*
- *What are the outcomes?*

- *How do these outcomes affect the mission?*

. To help answer these questions we turn to such methods as:

- PRA (Probability Risk Analysis). Borrowed from the nuclear power industry.
- Reliability diagrams and analysis
- Fault Trees
- Event Trees
- FMEA
- Data Analysis
- Modeling (Cost and Schedule models; Monte Carlo simulations)

Twenty-five pages of charts are used to support the material that is presented. Some of them are shown below

Reliability analysis

- In random failure region, failure rate, λ, = constant.

$\lambda = \frac{1}{N_S}\frac{d\,N_F}{d\,t}$ or $\frac{d\,N_F}{N_0 - N_F} = \lambda\, d\,t$ N_F = No. failed; N_S = No. still working; N_0 = Original No.

Which solves as $(N_0 - N_F) = N_S = N_0\, e^{-\lambda t}$

$\frac{N_S}{N_0} = e^{-\lambda t} = P_S$ probability of survival

$1 - P_S = 1 - e^{-\lambda t}$ = probability of failure, P_f.

In a system of n units in which a failure of any one results in a system failure,

$P_{ss} = P_{s1} \cdot P_{s2} \cdot \ldots P_{sn} = e^{-\lambda 1 t}\, e^{-\lambda 2 t} \ldots e^{-\lambda n t}) = e^{-(\lambda 1 + \lambda 2 + \ldots \lambda n)t}$

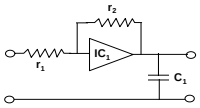
$P_{fs} = 1 - P_{ss} = 1 - e^{-(\lambda 1 + \lambda 2 + \ldots \lambda n)t}$

Spacecraft reliability

- **IF A UNIT FAILS WHEN ANY ONE OF ITS PARTS FAILS, THEN ITS P_S IS THE PRODUCT OF THE INDIVIDUAL PROBABILITIES.**

$P_{S,TOTAL} = P_{S1}\, P_{S2} \ldots P_{S\,n} = e^{-\lambda 1 t}\, e^{-\lambda 2 t} \ldots e^{-\lambda n t} = e^{-(\lambda 1 + \lambda 2 + \ldots \lambda n)t}$

EXAMPLE :



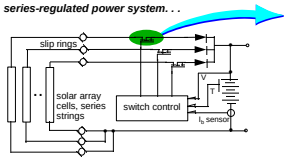
Part	Failure Rate, λ
r_1	0.1
r_2	0.1
IC_1	30.0
C_1	0.1
Total	30.3

but are all part failures lethal ? . . . . .

Spacecraft reliability

. . Not all failures are lethal

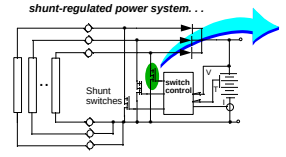
series-regulated power system. . .



FET switch failure modes. . .

- ***fails shorted***
  - ***. . . no loss of array power***
  - ***. . . lose control of one string***
- ***fails open***
  - ***. . . lose one solar array string***
  - ***. . . degraded array***

shunt-regulated power system. . .



Failure modes . . .

- *fails shorted*
  - *. . . lose one solar array string*
  - *. . . degraded array*
- ***fails open***
  - ***. . . no loss of array power***
  - ***. . . lose control of one string***

Redundancy math

- Independence: ***any redundant unit fails independent of its neighbor.***
- For N identical units, the probability that all will fail is :

$P_{F(all)} = P_{F1} \cdot P_{F2} \cdot P_{F3} \cdot \ldots\ldots P_{F(N)}$; or, since they are all alike, $P_{F(all)} = P_F{}^N$

- The probability that one or more of N will survive is :

$P_{S+} = 1 - P_F{}^N$

or, $P_{S+} = 1 - (1 - P_S)^N$

EXAMPLE 1 : let $P_S = 0.4$, and say there are 2 more redundant units (i.e.. N = 3),

$P_{S+} = 1 - (1 - 0.4)^3 = 0.784$ (fair improvement)

EXAMPLE 2 : let $P_S = 0.95$, and say there is only ONE additional unit, N = 2

$P_{S\,1} = 1 - (1 - .95)^2 = 0.9975$, MUCH BETTER !

Lesson: ***DO NOT RELY ON REDUNDANCY TO MAKE UP FOR POOR DESIGN !***

Redundancy math

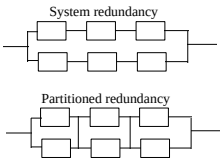
For redundant units which are independent of each other, the probability of all failing is $P_F = (P_f)^N$ if they are all alike.

The probability that at least one of the redundant units will survive is:

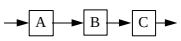
$P_{S1} = 1 - (P_F)^N = 1 - (1 - P_S)^N$

Consider two configurations of six units with equal λ.

Which is more reliable?

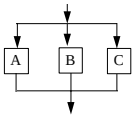


Series/parallel models



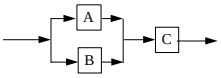
$P_S = P_{SA}P_{SB}P_{SC}$

Series Reliability



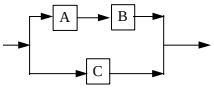
$P_S = 1 - (1-P_{SA})(1-P_{SB})(1-P_{SC})$

Full parallel redundancy



$P_S = P_{SC}[1-(1-P_{SA})(1-P_{SB})]$

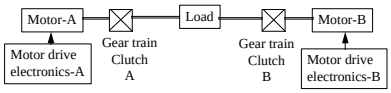
Partial redundancy



$P_S = 1 - (1- P_{SA}P_{SB})(1-P_{SC})$

Full, non-identical redundancy

Isolated Redundancy



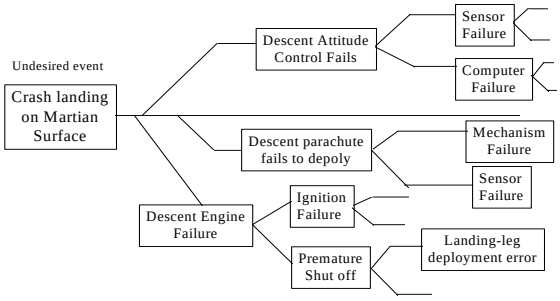
Flight Incident: "A" side clutch failed to engage and also failed to disengage to allow the "B" side to drive.

Analysis

- Redundancy isolation was not achieved. Both motors and both clutches should be individually commanded to turn on and off.
- Separate discrete commands for turn-on and turn-off of Motor-A and -B.

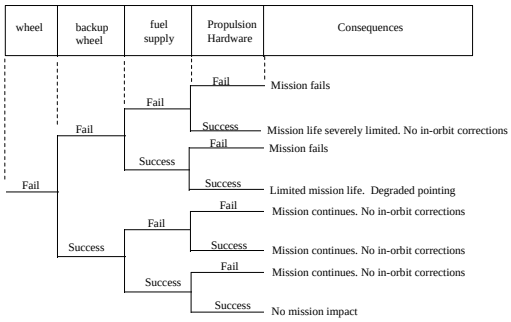
UARS Shared Experiences, GSFC, 1992

Fault Tree Example

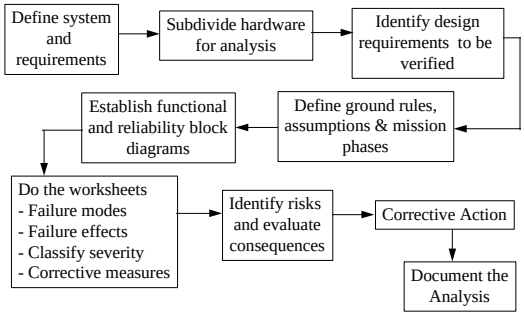


Event Trees

- Trace consequences through a series of events



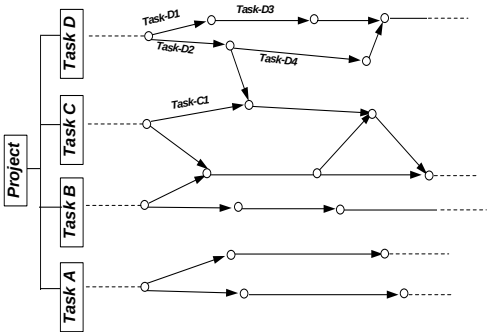
FMEA flow diagram



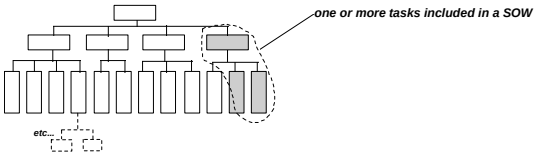
Tools and Techniques

As mentioned above, risk issues can be extracted from existing project documents, e.g., work breakdown structure, program schedule, cost allocation, test plan, and even parts lists. To further support these methods we turn to some specific tools and techniques. The course uses 21 charts for discussion, some of which are:

WBS as a schedule generator

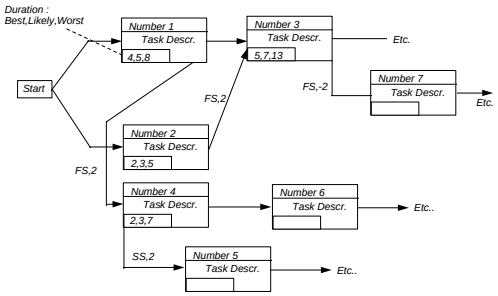


WBS as a SOW generator



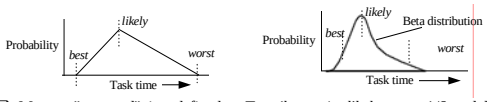
- *WBS assures all work has been identified*
- *Every WBS element should appear in only one SOW (except for parallel sourcing)*
- *Across-the-board requirements: Specify the level.*
  - *-- Reviews*
  - *-- Documentation*
  - *-- Support*
  - *-- Spares*
  - *-- FMEAs, WC analysis*

PERT mechanics



PERT's assessment of risk

- Task schedule uncertainties fall within a triangular or Beta distribution.



- Mean or "expected" time defined as Te = (*best* + 4 x *likely* + *worst*)/6, and the variance,

$$\sigma = \left(\frac{worst - best}{3.2}\right)$$

denominator depends on type of distribution and may vary from approx.. 2.5 to 5.

- According to Central Limit Theorem, mean time for entire path,

$$Te_{path} = Te_{task\text{-}1} + Te_{task\text{-}2} + ...Te_{task\text{-}n}$$

- Path $\sigma = \sqrt{\sigma^2_{task-1} + \sigma^2_{task-2} + ... \sigma^2_{task-n}}$

Risk mitigation. . . *using PERT example*

- Schedule/cost mitigation

  Reasonable approach:
  - Schedule reserve = 4.23 wks. (= 1 σ)
  - Cost reserve (assuming problem occurs at peak manpower point) = 4.23 wks. x maximum weekly running rate (Ex.: at $15k/wk, reserve = $63.5K (for that path).

  More conservative approach
  - Plan schedule reserve = 12.7 wks (= 3σ)
  - Cost reserve = $190K (again, for that path)
- Technical mitigation

  Analyze and find the threat, eliminate or modify it.
- Cost and Schedule mitigation

  Based on technical mitigation, redo the schedule numbers, re-calculate the T_e, σ's, and associated schedule and cost margins.

Monte Carlo method

- **A SIMULATION THAT SHOWS A RANGE OF POSSIBLE OUTCOMES DUE TO UNCERTAIN INPUTS, AND THE LIKELIHOOD OF ACHIEVING THEM.**
- **PROBLEM INPUTS ARE EXPRESSED AS PROBABILITY DISTRIBUTIONS**
- **EACH OUTCOME IS CALCULATED FROM RANDOMLY SELECTED VALUES FROM EACH INPUT DISTRIBUTION**
- **AVAILABLE SPREAD-SHEET TOOLS ON A MAC OR PC**

  Excel ®, or Lotus-123 ®, Crystal Ball ®, @Risk ®, or MonteCarlo ®

Cost Risk Assessment

Small-sat bus cost estimate

Structure	**3.15 M$**
Thermal	**1.3**
Attitude control	**1.9**
Propulsion	**1.5**
Power	**4.1**
T&C (comp+SW)	**3.6**
Harness	**.45**
Total	**16.01 M$**

Each of these estimates is an approximation based on one or more of the three H's: History (mostly), Hunch (sometimes) or Hope (minimally). Each falls within an expected best-to-worst range. Within its range each cost has some finite probability of occurring. The shape of the probability distribution depends on what we know about previous history.

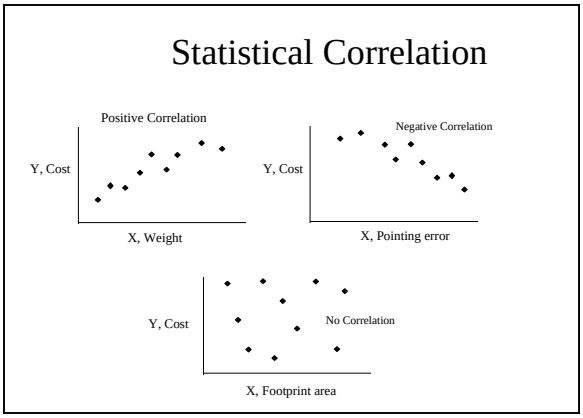
Evaluate the risk. . . . . .

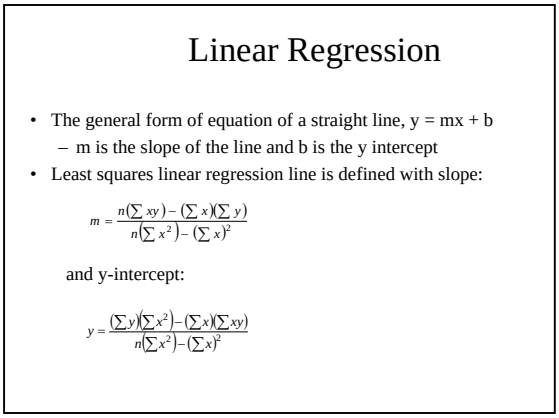
A Monte Carlo simulation of the small satellite cost example (left) is presented in class to illustrate how this method works. The cost uncertainties are expressed in terms of likely distributions and the results appear as a spread of outcomes, each with an attached probability. The advantage of this method is that it runs under available spread sheet programs, at great speed.

Risk Modeling

Risk modeling aims to uncover possible bad performance outcomes and consequences. Here "performance" means not only technical compliance but also schedule, cost, weight, life, reliability, and overall system suitability. Modeling is a broad subject; in this course we devote 34 charts to its discussion. There is as yet no single approach that embraces all these issues at once so they must be assessed separately. For the purely technical issues the best way, though complicated and difficult, is the previously mentioned Probability Risk Assessment (PRA) - about which, more later. For other risk factors - e.g., weight, cost and schedule -- we can turn to data about previous projects as a basis for identifying risk factors. For example, comparing measures like $/Kg or Watts/Kg or time-to-completion to known metrics may signal the extent of risk. Schedules with no reserve for failure can indicate a risky outcome, the consequences of which depend on its impact.

In the material that follows we consider ways to use historical data to determine risk-indicating metrics. There is plenty of data available on cost and weight, but it will be obvious that other performance features can be modeled that way too. As an example, say that a new sensor is projected to weigh 35 Kg and cost $12M. Does that pose a risk? The answer may lie in comparing its projected weight and cost to that of other earlier similar sensors. Since there is unlikely to be an exact match, one must construct a model that will signal the degree of risk. The method is straightforward: gather past data from projects that resemble the item to be evaluated; do a linear or logarithmic regression to fit a curve to the data and obtain a correlation factor to indicate the goodness of fit; use the resultant curve as a model to predict a most likely outcome for the feature in question. Commonly used spread-sheet programs have built in regression formulas for performing this task.





Weight relationships

Batteries	
NiCad	.05 Kg/W-Hr
NiH (Indiv. Press. Vessel	.027 Kg/W-Hr
NiH (Comm. Press. Vessel	.022 Kg/W-Hr
Li-ion	.01 Kg/W-Hr
Assembled battery (NiH)	.04 x Eclipse power + 26.8[1]
Solar Arrays	.02 x End-of-life power + 32[1]
Solar Array Drives	.065 x Array wt. + 3.01[1]
Structures	.073 x launch weight -24.9[1] S x launch weight[2]
Thermal	T x S/C power dissipation[3], or .023 x S/C power dissipation -9.2[1]
PC Boards	≈ 1 lb for 6x9-inch board[1]
Box enclosures	0.7 lb / ft² of wall for 50-mil aluminum[1]
TWTA's	.04 x Po + 2.34, Kg[1]
SSPA's	.0778 x Po+.51[1]

[1] Unpublished work by I.Brown, ICOM Satellite Co.
[2] 0.087 < S < 0.097, *Design of Geosynchronous Spacecraft*, B.N. Agrawal, Prentice Hall, 1986.
[3] 0.03 < T < 0.04, B.N. Agrawal

Spreadsheet modeling

EXAMPLE: ***Battery weight estimate for a new application with eclipse power = 900 watts***

Spread sheet: Lotus 123
Commands: /Data, Regression, Y-range, X-range, Output range, Y-intercept (compute)

	A	B	C	D	E	F	G
1	SPACECRAFT	Batt. Wt, Kg	Eclip pwr., W			Regression Output:	
2	SC-1	39.7	413	Constant			26.76355
3	SC-2	78.2	1223	Std Err of Y Est			7.004415
4	SC-3	121.0	2200	R Squared			0.983542
5	SC-4	137.0	2969	No of Observations			5
6	SC-5	157.0	3189	Degrees of Freedom			3
7							
8				X Coefficient(s)		0.039938	
9				Std Err of Coef.		0.002983	

Battery weight, Kg = 0.04 x EOL Eclipse power + 26.8

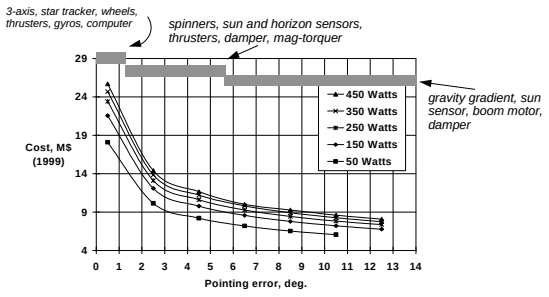
The aforementioned parameters such as $/Kg are tyical of those used in modeling techniques known as CER (Cost Estimating Relationships). These models use historical data as a basis to predict probable cost outcomes of similar systems and components. Weight, volume, power, etc. are generally the most significant parameters, but additional factors such as technical complexity, margin, schedule, etc. can be factored into the projection. Models such as PRICE, USCM-7, NAFCOM99, are typical of this genre.

Recognizing that basic cost models often fall short of the actual end costs, NASA GSFC has developed an interesting method of adjusting cost model results according to an assessment of the risks involved; in this case, for several categories of scientific instruments. This course explains this method as an example of how CERs can be adapted to fit special risk situations.

Aerospace Corporation investigators have noted that in the case of small satellites cost of their bus subsystems can be modeled as a function of performance factors like pointing error and power.

$ vs Performance

. . . power, pointing error



Software Risks

It is well known that projections of software technical performance, cost and schedule must be adjusted for risk. Starting with a basic assumption that software effort begins with an estimate of the total lines of code, risk factors are applied that reflect the environment in which the software is conceived, developed and tested, its prior history, etc. Note these environment factors in the chart below. Several examples of how software risks affect cost outcomes are presented in the course.

Software environment factors

	Sensitivity range		Sensitivity range
Analyst capability	.7 - 1.5	Product reliability	.75 - 1.4
programmer capability	.7 - 1.42	Data base size	.94 - 1.16
Applications experience	.82 -1.3	Product complexity	.7 - 1.65
Virtual machine experience	.9 - 1.21	Required reuse	1 - 1.5
Prog. language experience	.95 - 1.14	Modern programming practices	.82 - 1.24
Execution time constraint	1 - 1.66	Use of software tools	.62 - 1.24
Main storage constraint	1 - 1.56	Required security	1 - 1.1
Virtual machine volatility	.87 - 1.49	Required schedule	User prompt*
Computer turnaround time	.79 - 1.15	Management risk reserve	1 - 2
Requirements volatility	.9 - 1.62		

Use this factor very carefully only to assess the upper limits of program cost

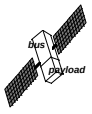
** User can change the model-computed schedule, but not less than 75% of the computed value. Model will change manpower requirements accordingly.*

very low program risk (ground systems)	= 1.0
low risk military ground systems	= 1.2
medium risk (unmanned airborne)	= 1.4
high risk (manned airborne)	= 1.6
very high risk (unmanned space apps)	= 1.8
extra high risk (manned space apps)	= 2.0

Design Issues

A number of risk issues confront design, manufacutre, and test of aerospace items, expressed in 34 charts. These cover on-orbit environment factors such as vacuum, atmospheric and particle drag, plasma, radiation, solar pressure, debris, and zero-g. Information is presented on the distribution of single-event effects. An example of weight risk is worked out. Risks in mechanisms for deployment of solar arrays, antennas and masts, are presented. Lessons learned from the use of rotation devices in various projects are covered. An example of risk arising from contrasting choices of power system configurations is presented. Structure design tradeoffs and their effect on risk, weight and design margin is presented and discussed. Risk-related test issues, e.g., vibration margins, RF breakdown, 0-g simulation, thermal model confirmation are also covered.

Weight risk. . *an example*



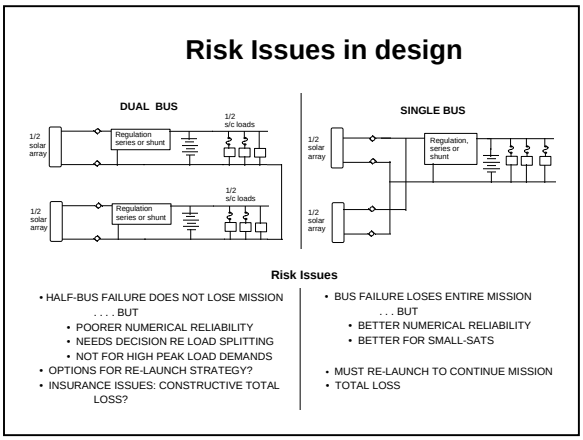
Mission . . . geo-synch orbit, 10-year life
. . . sun-tracking solar arrays
. . . full eclipse operation
. . . launch from CCAFS (Canaveral), Delta launch
Delivery . . . 30 months from now

Initial weight, power projection

	Weight (kg)	Power (w)
Payload	200	1500.
Bus	557	377.
Total dry weight	757	
Sta.-keep fuel	173.	
Apogee fuel	744	
Total launch weight	1674	
Total power		1877.
Delta Capability	1820	
Margin	146	

Major findings -- retention/release mechanisms

- In past 23 years, 84 pyrotechnic device anomalies (12 in flight with qualified hardware)
  - 35 due to inadequate understanding of the technology
  - 24 due to mistakes in design
  - remainder due to poor procedures and quality control.
- Untested flight sequence can result in unexpected events.
- Mechanical joints requiring precise alignment should not depend on friction to hold alignment during launch vibration.
  - Use match drill and pins or bolts.
- Deployed cover seals
  - Avoid covered O-rings if possible. Prefer teflon seals
  - Ensure that the seal is actively broken by high-force actuator



Test program risks

- Confirming the S/C thermal model
- Testing deployable subassemblies
- Non-testables:
  - Attitude control systems
  - Propulsion devices
  - Pyrotechnic devices
- Isolating system errors in test data flows
- Necessary compromises in thermal/vac test
  - Solar array removal
  - RF equipment testing

Risk in COTS

Cost- and schedule-reduction pessure has focussed attention on using commercial off-the-shelf (COTS) parts. Although they are used selectively on many commercial space programs, and more recently on NASA and Air Force programs, they are not without additional risk. This topic is explored in a series of thirteen charts, reviewing their test history in successful programs, methods of upgrading their reliability and radiation hardness.

Better, Faster, Cheaper

Perhaps no space design philosophy has focussed on the issue of risk more than Better, Faster, Cheaper. Voices and emotions have been raised both praising it and condemning it. We present 13 charts that fairly covers its pros and cons, its history since its inception in 1992 and ways to address its risk and mitigation.

Lessons from the Mars Programs

The many Mars exploration missions from 1975 to the present exemplify how program and system engineering choices deal with risk. We examine their successes (Global surveyor, Pathfinder, Deep Space 1, and Spirit and Opportunity Rovers) and their failures (Climate Orbiter, Polar Lander, Deep Space 2) with an eye to learning how the risks played out in both sets of programs. A good summary is available in the findings of the Mars Program Independent Assessment Team.

How would you handle this situation?

Typical risk-related problems that have popped up in past programs are examined. The pros and cons of possible outcomes are not obvious and it is left to class discussion to make a case for how to manage these risks.

An historical example

In 1972, RCA was awarded a cost-reimbursable contract by Martin-Marietta to supply all the S-band and UHF communications equipment for the Viking Mars Lander, a project of national interest. Schedule was critical because of a 1-month launch window only once every 26 months. RCA's proposal had been based on using a Motorola S-band receiver, a complex narrow-band unit which relied on frequency tracking to cope with Doppler shift. It was a mid-1960's design using conventional rf design practices on large PC-boards. The circuitry had been previously qualified and flown on JPL missions, but it needed some form and fit repackaging. A competing design by Ford Aerospace (now Loral) had been briefly considered. It was smaller than Motorola's and weighed about 10 lbs. less, but relied on unproven chip-on-ceramic technology still in development. Some component samples had been built with promising results, but the receiver was still a long way from qualification. Nevertheless, Ford management was confident enough to say it would take a fixed price contract from RCA.

As RCA prepared to negotiate with Motorola, Martin-Marietta announced to all its subcontractors that a serious weight problem had been uncovered for the Lander as a whole. So serious, in fact, that it offered a $75,000 per pound inducement to any contractor who would reduce hardware specification weight. Of course, the contractor had to show that the reduction was reasonable and achievable. The fee payment would be made on the spot.

This posed an interesting dilemma. RCA could stay with the Motorola design and forego the added fee, or opt for Ford-Aerospace's unproven design, gain an immediate 10-pound weight reduction and the $750,000 fee that went with it, but at much greater technical and schedule risk.

A lively in-house debate erupted. RCA-Astro's VP and General Manager saw it as a bottom-line issue. "Do you realize how much business we must book to make $750,000 in fee? This is being handed to us on a silver platter!" The Project Manager saw it differently. "We're risking our necks and threatening the 1975 launch window. No amount of fee is worth that!" The VP/GM countered that if problems developed, "we'll throw our own resources into it, do whatever it takes." (Of course, under a CPFF contract that would increase direct cost and diminish the percent fee somewhat).

It was a "gut" issue. People's careers could be affected. There were no "lessons-learned" experiences to rely on.

How do you think this played out ?

A Proposal Example

In 1980, Company X responded to a request for proposal for a communication satellite. Its performance requirements were substantial, and Company X's proposed design had a launch weight margin of less than 5%. At that time, two new as-yet unqualified technology developments became available which promised substantial weight reductions. One was the nickel-hydrogen battery cell which had a watt-hour/kg ratio of about 40, almost twice that of the conventional nickel-cadmium cell. Since the battery drain was estimated to be 1500 watt-hrs, the potential weight saving was about 75 kg.

The other development was a new concept for electrically pre-heating hydrazine before its ignition in small station-keeping thrusters. The increase in performance over conventional hydrazine thrusters was substantial. The increase in specific impulse (about 270 seconds for the electrically-heated thruster vs about 210 seconds for the conventional thruster) would result in about a 30% saving in hydrazine fuel.

Together, these weight savings would push the launch weight margin up to about 13 %. This was simply too big to ignore, even though their cost and delivery schedule exceeded that of the conventional items. Their additional cost would increase the proposed total price of $70M by about 5%. The extra schedule time would not increase the proposed delivery, but it would cut the schedule reserve of three months by about a half.

Management was faced with a risk dilemma: Sacrifice a $3.5M competitive cost advantage and schedule reserve versus increasing the launch weight margin. Recognizing that a smart customer would also weigh these pluses and minus in selecting the winning proposal, how do you think this played out?

Consider what options Company X might have for mitigating the risks of one option versus the other.

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