Managing Uncertainty and Risk in Public Sector Investments

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Managing DoD IT Infrastructure Investments

The DoD annual budget approaches a half trillion dollars

- Much of that budget is invested either directly or indirectly affected by Information Technology Infrastructure modernization initiatives

- Because there is no market for public sector goods, efficient resource utilization is a challenge

Cost/Complexity Drivers

- Complexity increases exponentially with size, rate and scope of technology innovation
- Cost of integration is driven by the exceptional complexity of IT infrastructure

✓DoD is exploring the building of system-of-systems, and federation of systems

Measures of Effectiveness for Public Sector Investment

- Do not capture underlying process dynamics
- Are hard to apply
- Tend to be not timely - Are lagging indicators
- Are vulnerable to “gaming”

Impact to Public Sector Investment

- Systemic under estimation of cost and schedule at the onset of major systems/ software programs
- Accountability difficult to establish
- Often deliver less value than promised

Investment in the Public Sector

Unlike the Private Sector, Public Sector markets lacks mechanisms for:

- Self-regulation
- Rapid knowledge dissemination and aggregation
- “Inherent” incentives linking expenditures and and accountability

Pricing with Markets

- In the Private Sector risk and reward are set by Competitive Markets

- The price of a stock represents the market consensus of the value of a Firm
  - Which may/may not be accurate

- Value depends on delivering the right product efficiently

Pricing Without Markets

- No clear way to link price and value
- But the price of a Public Sector firm ultimately depends on its internal efficiency
- In theory, internal efficiency based valuation and and market valuations should converge to a single value
- Internal efficiencies are measurable
  - ✓ Regardless of whether the Firm is in Private or Public Sector

What Competitive Markets Do

- Enable a rapid consensus of a Firm's worth
  - Its value – its measure is the price

- The factors governing that consensus are:

✓The rate at which information becomes known

✓The rate at which price/risk information is aggregated (e.g., decision formation)

The Basis of Price Formation

- Knowledge Diffusion Rate
  - ✓Tends to keep rule violations in-check

- Information Aggregation Rate
  - ✓Bounds the timeliness & quality of investment decisions

Information Diffusion and Aggregation Rates

- Determine whether, and at what rate, price consensus occurs
- Indicate market efficiency
  - ✓ Sub-optimal rates result in price discrepancies that can be exploited by floor traders, value investors, and others

Uncertainty, Risk and Investment Valuation

- Initial project cost/schedules estimates are subject to significant uncertainty
- The ability to reduce uncertainty and risk depends significantly on a Firm’s internal efficiencies
- That ability is a consequence of the Firm’s internal efficiencies
  - ✓ Its measure is a “synthetic price”

Investment Risk Drivers
Software intensive systems

Three primary risk drivers:

- Technical complexity
- System Integration complexity
- Project size and duration

These risks govern uncertainty, irreversibility, and timing for IT infrastructure investments in both the Private and Public Sectors

IT Infrastructure Investment Parameters

- **Uncertainty**
  - ✓Software intensive systems are particularly sensitive to the under-estimation of risk
  - ✓The level of complexity is hard to comprehend, let alone manage or measure
- **Timing**
  - ✓Technology investments can be rendered obsolete by:
    - New technology
    - Evolving threats

Investment Management Parameters

- **Irreversibility**
  - Investment is allocated to the labor required to develop the intellectual capital embedded in software is unrecoverable
    - ✓ Zero salvage value unless deployed

- Large scale IT infra-structure investments are particularly susceptible to these parameters

- Mastery of internal operating efficiencies is crucial

Special and Common Causes of Variability

- Perturbations in a Firm’s performance derive from two sources of variability:
- *Common causes*: Poorly defined requirements, processes, procedures, aging equipment
  - ✓ These are entirely controllable
  - ✓ Are the focus of 6-Sigma, the CMMI
- *Special causes*: equipment failures, spikes in staff turnover, unrecognized sources of integration complexity, etc.

The Impact of Variability

- A Firm's performance, and risk, is governed by the ability to master these two primary causes of variability

- Less efficient Firms will exhibit growing variability overtime/declining performance, regardless of sector: Public or Private

- Variability propagates uncertainty thus driving risk - via delays in decision making
  - ✓ The time value of available information degrades at an accelerates rate

Variability and Response Perturbations

- Variability drives system perturbations
  - ✓Which are stochastic
- Perturbation responses indicate the efficiency of underlying of information diffusion & aggregation rates
- The rates are not directly observable
  - ✓But govern “synthetic” price formation

The Basis for Synthetic Prices

- A Firm is a stochastic feedback system that can be modeled using algorithms from System Control and Information Theory
- The efficiencies of information utilization are quantifiable as “Information Gains” - derived from a Kalman Filter
- But, producing information gains:
  - ✓ Consumes resources (time, labor, technology)
  - ✓ Produces benefits (e.g., on-time product/service delivery)

The Relation between Synthetic Price and Black-Scholes Models

Common Objective:

Both determine the “worth” of an investment as measured against various combinations of risk, uncertainty, interest rates, and competing investment opportunities

✓Neither predict which Firms are most likely to succeed

Both Synthetic Price and Black-Scholes models:

- Are based on the Law of Large Numbers
- Converge, in the limit, to “true” market based valuations

Capital Asset Pricing
The Black-Scholes Model

Black-Scholes assumes that stocks have a true value that:

- Corresponds to its risk
- Determines whether the market price for a stock is too high or tool low

⇨A stock option’s value equals the value of the information concerning that risk

Significance of Black-Scholes

- Stock Value dynamics are modeled as Brownian Motion process
- Captures market dynamics in terms of a few variables
- Provides a (real time) computationally efficient models that link price, interest, and discount rates
- Eschews unobservable/hard to measure parameters such as “Investor Psychology”

✓Demonstrates that effective decision making need not depend on a detailed understanding of causality

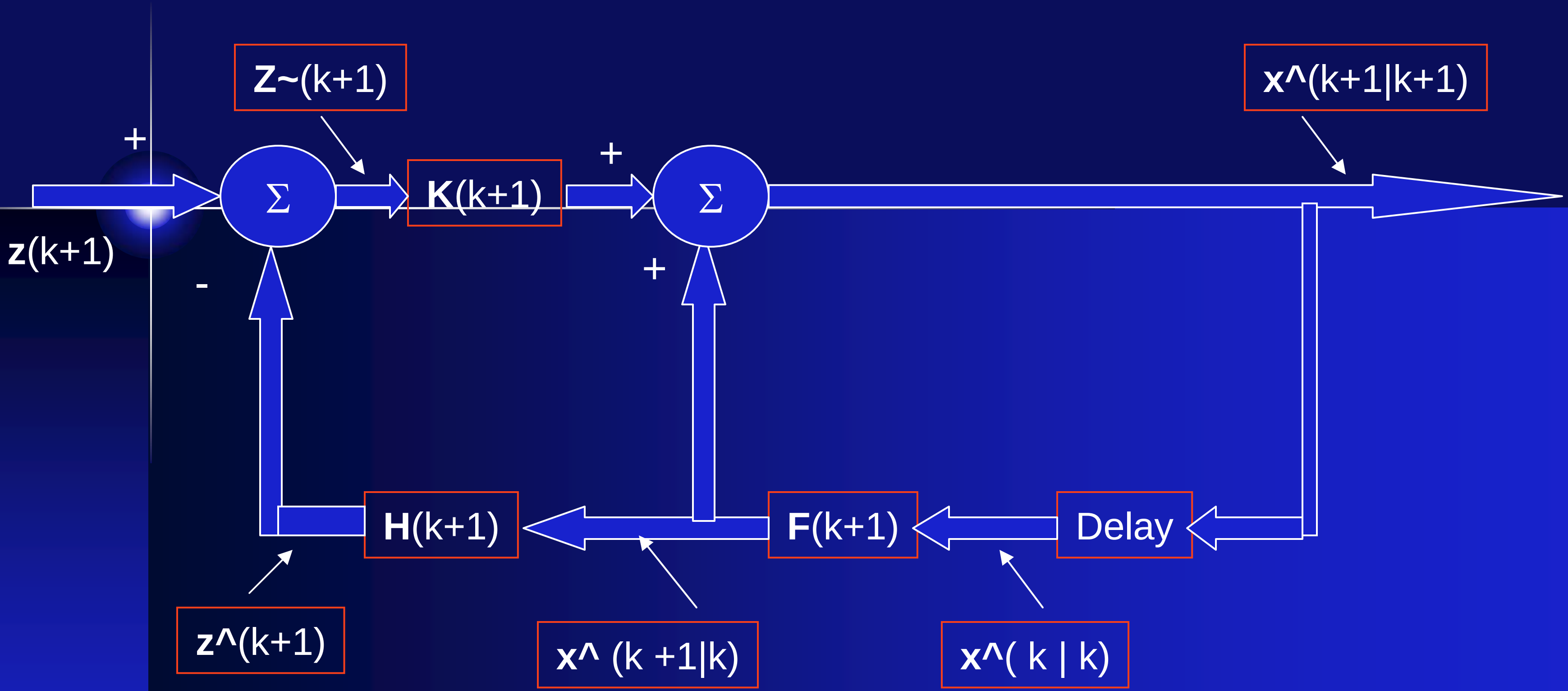
Synthetic Pricing - Measuring Information Gains

Apply Kalman Filter models to measure:

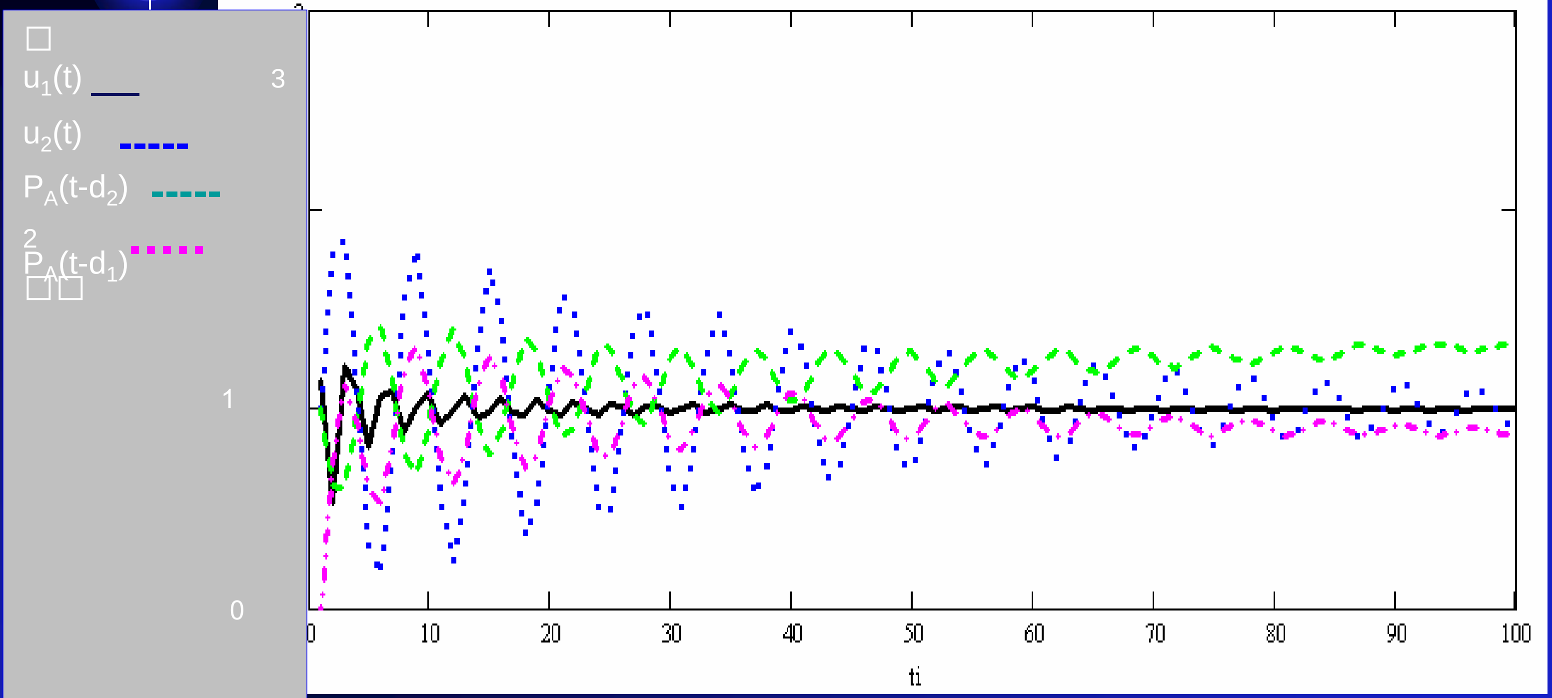
- ▸How uncertainty propagates over time
- ▸The information carrying capacity/efficiency of a Firm
  - ✓And thus its value

Synthetic prices are measurable as a “gain” in a Kalman Filter

Kalman Filter Schematic



Output from Kalman Filter Model



Legend

$u_1(t)$ - input forcing function -special variability cause

$u_2(t)$ - input - common variability cause

Are damped out by steady process improvement

$P_A(t-d_2)$ - Error propagation (variability) driven by “long” delay

$P_A(t- d_1)$- Impact of “short” delay on system ability to minimize error propagation for $(d_1 < d_2)$

Next Steps

- ▸Validate that Perturbation based measures converge, in the limit, to the market based valuations

- ▸Get data for several hundred public & private sector Firms;
✓Normalize the data across the Public and Private sector

- ▸Quantitatively estimate efficiency and information gain parameters

- ▸Validate models against the predictions they make

Backup Slides

Computation Notes

- **x** a vector of variables comprising the system, whose state is to be estimated over the successive time (e.g., multi-stage investment) periods k =0,1,2,…
- **x** ^ (k+1|k): The predicted estimate of **x** for time “k+1” based on measures taken at time “k”
- **z**: the actual, uncorrected measurement of **x**
- **z** ~:The estimate of **x** when corrected errors introduced by the measurement process
- **z** ^ : The estimate of **x** ^ as filtered by **H**
- **H**: The measurement transformation matrix that relates the system state vector, **x**, to its measure, **z**

Project Success Data

Company Size	Success Rate '94	Success Rate '98	Project Cost '94	True Cost '98	Delta
Large	9%	24%	$2.3M	$1.2M	-65%
Medium	16%	28%	$1.3M	$1.2M	-41%
Small	28%	32%	$.4M	$1.1M	-4%

Turning Chaos into Success Jim Johnson www.SoftwareMag.com, 12/99

Ito’s Lemma

- Use to analyze processes without time derivatives, including output prices, input costs, etc… that cannot be manipulated using the ordinary rules of calculus
- The fundamental Theorem of Stochastic Calculus- use to analyze infrequent, discrete jumps
- Kolmogorov equation describe the dynamics of the pdf for a stochastic process

Problem Dimensionality

- Model Time frames: short/long term
- Sources of variability: common/special
- Levels of analysis: Micro/macro
- Uncertainty and Risk
- Forcing functions: stochastic
- Response functions: profit driven/”inspection” driven
- System Stability range…
- Transient/Steady state response

Cost Estimate Uncertainty Reduction as a Function of Project Life Cycle & Process Maturity Level

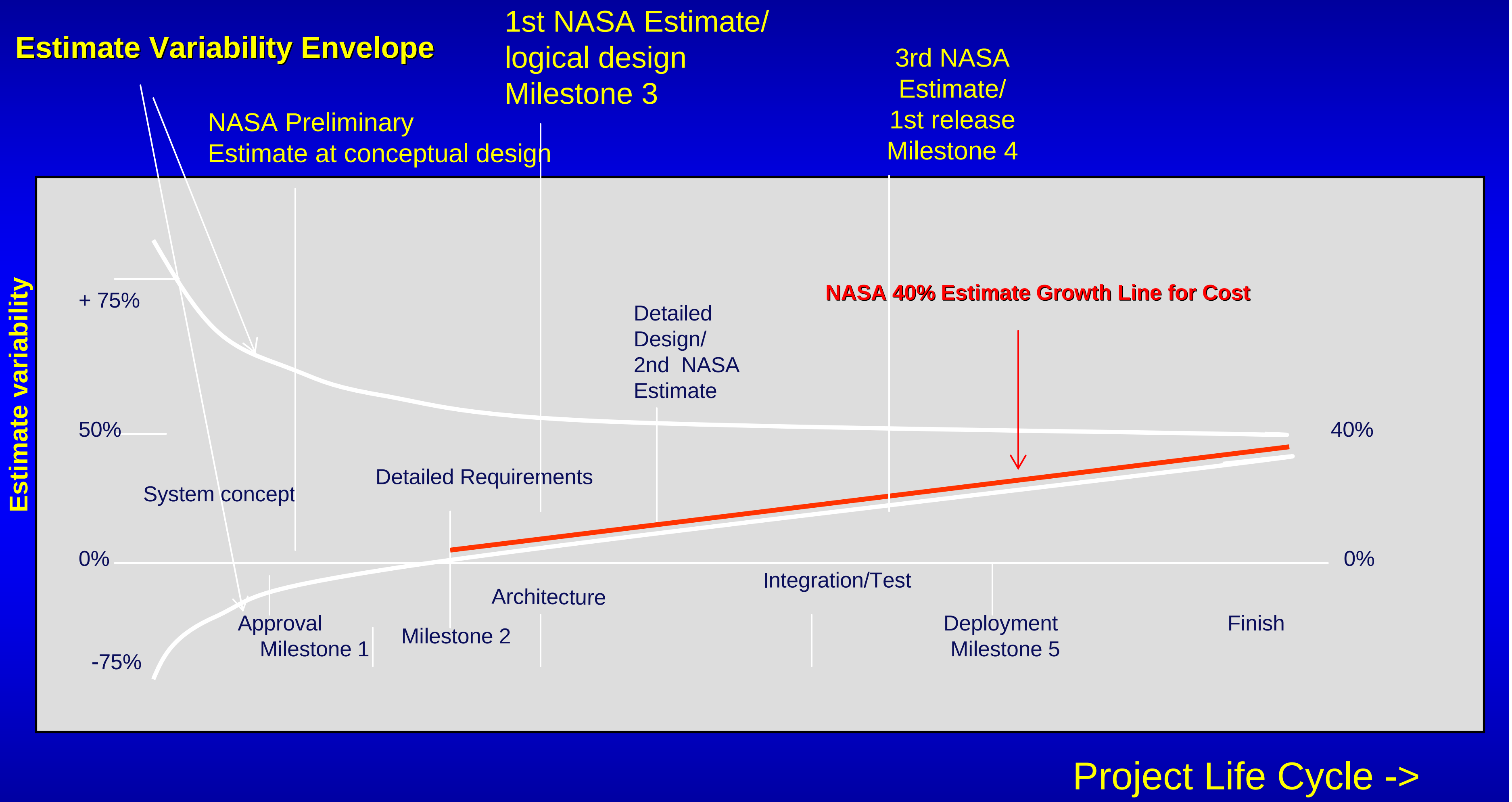


Figure 3: CMM Level 3 Projects at NASA - Software Engineering Laboratory (SEL) (http://www.nasa.goddard.gov)