Review of whole course

- A thumbnail outline of major elements
- Intended as a study guide
- Emphasis on key points to be mastered

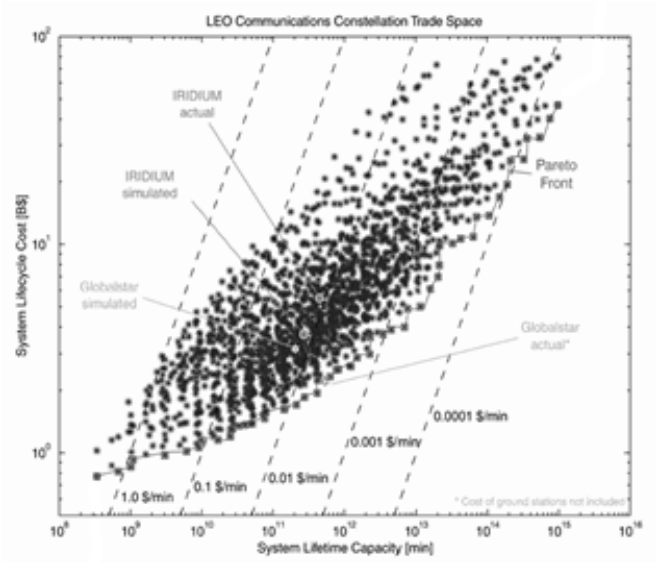
Major Elements Covered (1st half)

- Modeling of production possibilities
- Valuation Issues
  - over time – DR as opportunity cost, CAPM
  - evaluation criteria
- Optimization of production and cost
  - marginal analysis
  - constrained optimization
- Decision Analysis
  - Trees and Analysis
  - Value of Information

Modeling of Production Possibilities

- **Basic Concept: Production Function**
  - locus of technical efficiency
  - defined in terms of technology only
- **Characteristics**
  - marginal products, marginal rates of substitution
  - isoquants -- loci of equal production
  - returns to scale (≠ economies of scale!)
  - convexity of feasible region? Know when!
- **Generally defined by systems models that calculate performance of possibilities**

Trade Space



Valuation Issues -- over time

- Resources have value over time
  - Discount rate (DR) , r %/period
  - Formulas; e^{rt} for continuous compounding
- Choice of discount rate defined by best alternatives, at the margin
- DR ~ 10% or more -- long term benefits beyond 20 years have little consequence
- Money may change value via inflation
- Make sure you compare like with like

Valuation Issues: CAPM

- Capital Asset Pricing Model Adjusts Discount Rate to reflect "risk aversion"
- Accounts for Unavoidable (market) risks
- Assumes Project risks can be avoided
  - for investors, not so simple for owners
- Discount rate adjusted for relative volatility (by beta)
- r = r (risk free)
  + (beta) [risk (market) - risk (free)]

Valuation issues-- criteria

- Many types -- none best for all cases
  - Net Present value -- no measure of scale
  - Benefit / Cost -- sensitive to recurring costs
  - Cost / Effectiveness -- no notion of value
  - Internal Rate of Return -- ambiguous, does not reflect actual time value of money
  - Pay-Back Period -- omits later returns
- Choose according to situation (if allowed)
- In practice, people may use several criteria

Optimization -- Marginal Analysis

- Economic efficiency merges technical opportunities (Prod. Fcn) and Values (Costs)
- For continuous functions, convex feasible region in domain of isoquants
- Optimization subject to Constraints
  - Optimum when MP/MC ratios all equal
  - Expansion path is locus of resources that define optimal designs
  - Cost function: Cost = f(Optimum Production)
  - Economies of Scale ($\neq$ increasing returns to scale)
- Good Concepts, often not applicable in detail

Recognition of Risk

- Psychologically
  - Resistance to acceptance of this basic fact
- Descriptively: Forecast always wrong
  - Reasons: "surprises", "trend-breakers"
  - Examples: technical, market, political
- Theoretically: Forecasts => "house of cards"
  - Data range
  - Drivers of phenomenon (independent variables)
  - Form of these variables
  - Equation for model

Analysis under Uncertainty

- Primitive Models
  - sensitivity to irrelevant alternatives, states
  - sensitivity to basis of normalization
- Decision Analysis
  - Organization of Tree
  - Analysis
- Results
  - ≠ those on Average forecasts (flaw of averages)
  - Middle road, that provides flexibility to respond
  - Second best choices, flexibility costs

Value of Information

- Extra information has value
  - Value taken as improvement over base case
  - Is compared to cost of getting information
- Value of Perfect Information
  - Purely hypothetical / Easy to calculate
  - Provides easy upper bound
- Value of Sample information
  - Bayes' Theorem
  - Repeated calculations
  - Worthwhile in important choices

Major Elements Covered (2nd half)

- Concept: Option = "right, but not obligation"
  - Financial, "on" and "in" systems
- Lattice for future evolution
- Dynamic Programming for Optimization
  - Path independence
  - Cumulative return function
- Arbitrage pricing of options
  - Concept, development of Black-Scholes Approach
  - Meaning of "q" = risk-neutral "probabilities"
- Issues in the choice of methods…

Options

- Concept:
  - A right … but not an obligation
  - to do something (buy, sell, change design…)
  - at a price
- Financial -- those referring to traded assets
  - Calls, Puts (~ insurance) // American, European
- "Real" -- Applied to physical projects
  - "on" and "in" projects
- The Mantra of the 3 types of options

Lattice Analysis

- Like a Decision Tree
- Binomial approach ➔ recombination cell merges ➔ analysis linear in N, stages
- Easily reproduces Normal and LogNormal distributions assumed associated with random events
- Formulas for u, d, and p depend on
  - Sigma, the standard deviation
  - "nu", the average rate of growth
  - $p = 0.5 + 0.5\,(v/\sigma)\sqrt{\Delta T}$ $\quad u = e^{\sigma\sqrt{\Delta T}} = 1/d$

Expected Value with Lattice

- Since Lattice provides easy way to represent distribution …
- Can be used to show effect of uncertainty on value of project
- A (relatively) easy way to demonstrate
  - Importance of considering Uncertainty
  - Possibility of Major gains and losses
- Motivates Analysis of Options

Dynamic Programming

- Based on concept of independent "stages" that can assume variety of "states"
  - Easiest to visualize as time, space sequences
  - Can apply to separate projects…
- Implicitly enumerates all possibilities
- Thus, works over non-convex feasible regions
  - Crucial for situations with exponential growth
- Basic formula – cumulative return function

  $f_S(K)$ = Max or Min of $[g_i X_i , f_{S-1}(K)]$

DP Valuation of Option

- DP is the way to value options in lattice
- Proceeds from end states…
  - Knowing these possibilities, can calculate best choice for previous stage
  - Repeats to beginning
  - Obtains best choice for each state in each stage
- Calculation of "best choice"
  - "do nothing" versus "exercise option" values
  - value = discounted expected value of outcomes

Arbitrage Valuation of Options

- This is the "theoretically correct" view
- Assumes
  - Market for asset
  - "replicating portfolio" (RP) can be constructed
- RP defines a value for Option – which is NOT expected value – it is "Arbitrage Enforced"
- Valuation
  - At Risk-free discount rate (because of Arbitrage)
  - Of properly weighted proportion of asset, loan
  - ➔ Black-Scholes formula

"Arbitrage Enforced" Valuation

- In Lattice, same procedure as previously presented
- However, special features:
  - q = risk-neutral "probability" = [(1+ rf) – d] /(u – d)
  - discount at each stage using risk-free rate rf
- This approach is
  - Standard basis for all valuations of financial options
  - Limited application to options "in" systems, for which no markets may exist
  - Unclear when suitable for options "on" systems

Valuation of Options: Practice

- For Real options, finance theory may not work
  - No traded assets, so "arbitrage-enforced" not right
  - no statistical history, to determine sigma, nu
- Understand range of Alternative approaches
  - Decision Tree (Kodak)
  - Simulation (Antamina)
  - Hybrid (Ford -- Neely)
- Calculation issues
  - What design element should be flexible (Kalligeros)
  - Path Dependent Analysis (Wang)

Valuation of Real Options: Issues

- What is the "asset" involved modeling?
  - NPV of project?
  - What drives or affects that value?
- What is variability of project?
  - Historical Data may not exist
  - Data may not be random
- How do we develop results?
  - What can engineering team handle?
- How to we explain results?
  - What can client or audience handle?

Research issues in Options

- What method best in practice?
  - Formal real options analysis
  - decision analysis
  - net present value in some form?
- How to apply in specific areas, depending on
  - Economies of Scale
  - Path dependency over time
  - Interactions between design features
- How to present results to owners/managers of major projects?

Some Closing Thoughts

System designers need to:

- **Think beyond technical mechanics to performance of system in context**
  - **Communications Satellite –**
  - **technically brilliant but abysmal failure as system**
- **Value Flexibility systematically**
- **Monitor System, to know when to use option**
- **Maintain flexibility to act – don't let yourself get locked into a fixed plan**

Best Wishes on exam and for rest of your studies!

The teachers really hope you will do excellently!
(and make us look good!)

We've enjoyed being with you and
hope our relationship
can grow over time

Richard
Konstantinos, Lara, Maggie, Sgouris, Tao