OLAP for Optimum Asset Allocation under Uncertainty

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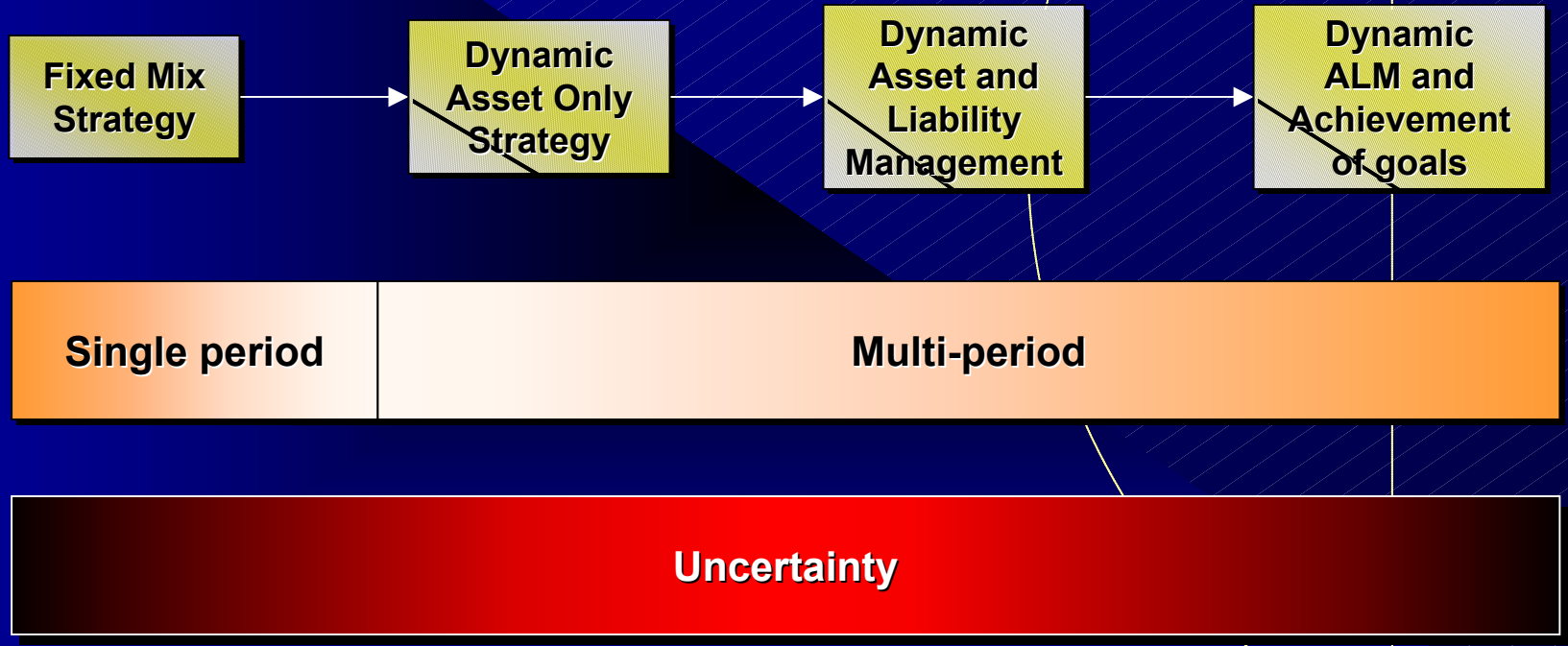
Outline

- **Optimum Asset Allocation**
- On-Line Analytical Processing for DSS
- OLAP for Asset Allocation using 2-stage Stochastic Programming

Evolution of Optimum Asset Allocation Models



Disadvantages of traditional approaches (1/2)

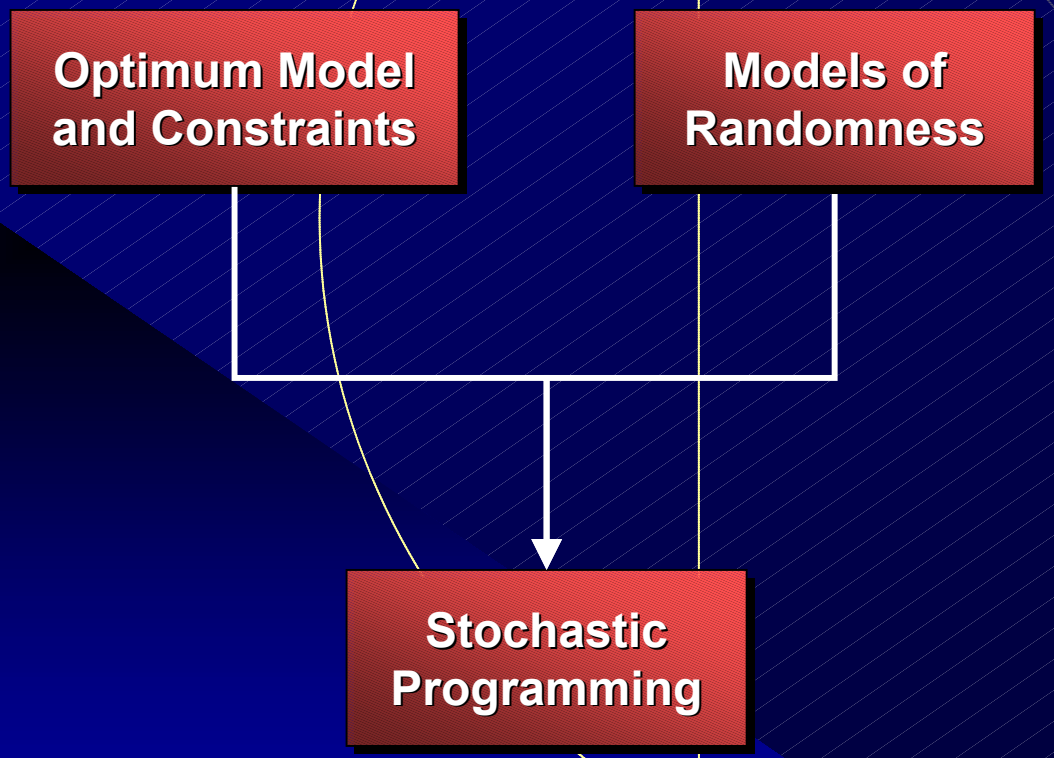
- **The single period nature of the model.** No long-term impact of short-term objectives.
- **The effect of errors in mean.** Although errors in variances in comparison with errors in co-variances seem to have twice a damaging impact in the decisions, the effect from errors in means have ten times greater impact.
- **The symmetric definition of risk.** Such a measure penalises negative and positive returns.
- **Computational burden.** Markowitz recommends $n(n+1)/2$ constants have to be computed for the model. Large-scale, dense quadratic programs, are difficult to solve for $n>500$. (MAD formulations overcome this difficulty)

Disadvantages of traditional approaches (2/2)

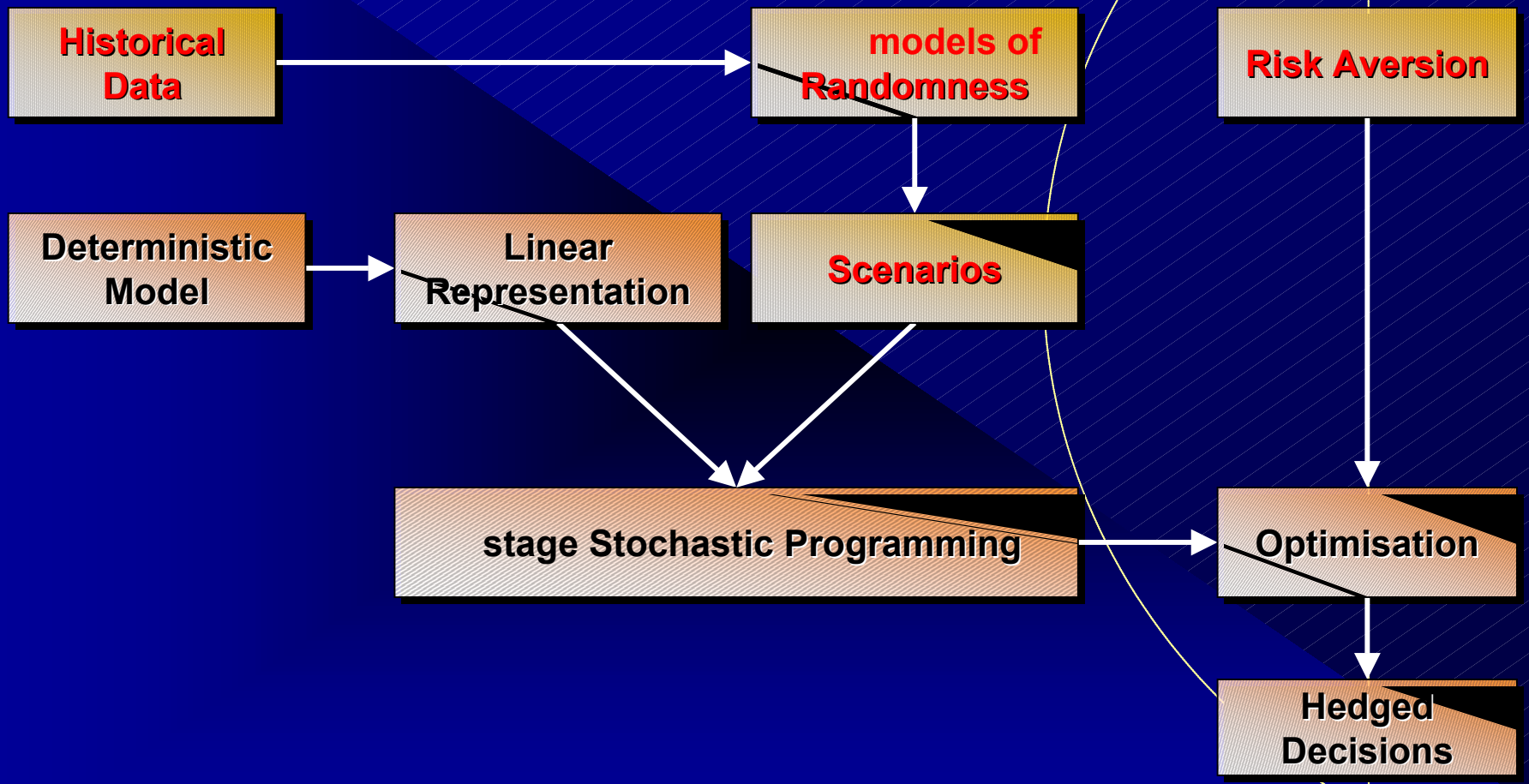
- **Transaction costs.** An optimal solution often results in many buy and sell decisions which can be costly if transaction costs are taken into consideration.
- **Management costs and cut-off effect.** Typical optimal solutions usually suggest a portfolio with a large number of assets; a difficult task that is not practised in reality. Also trading decisions may not meet the minimum transaction lots. Either the decisions need adjustment or a more complex integer quadratic program has to be solved.
- **Randomness ~N(μ, σ). Randomness is Normally distributed.** The Normal Distribution is not necessarily the 'norm.'

Why Stochastic Programming?

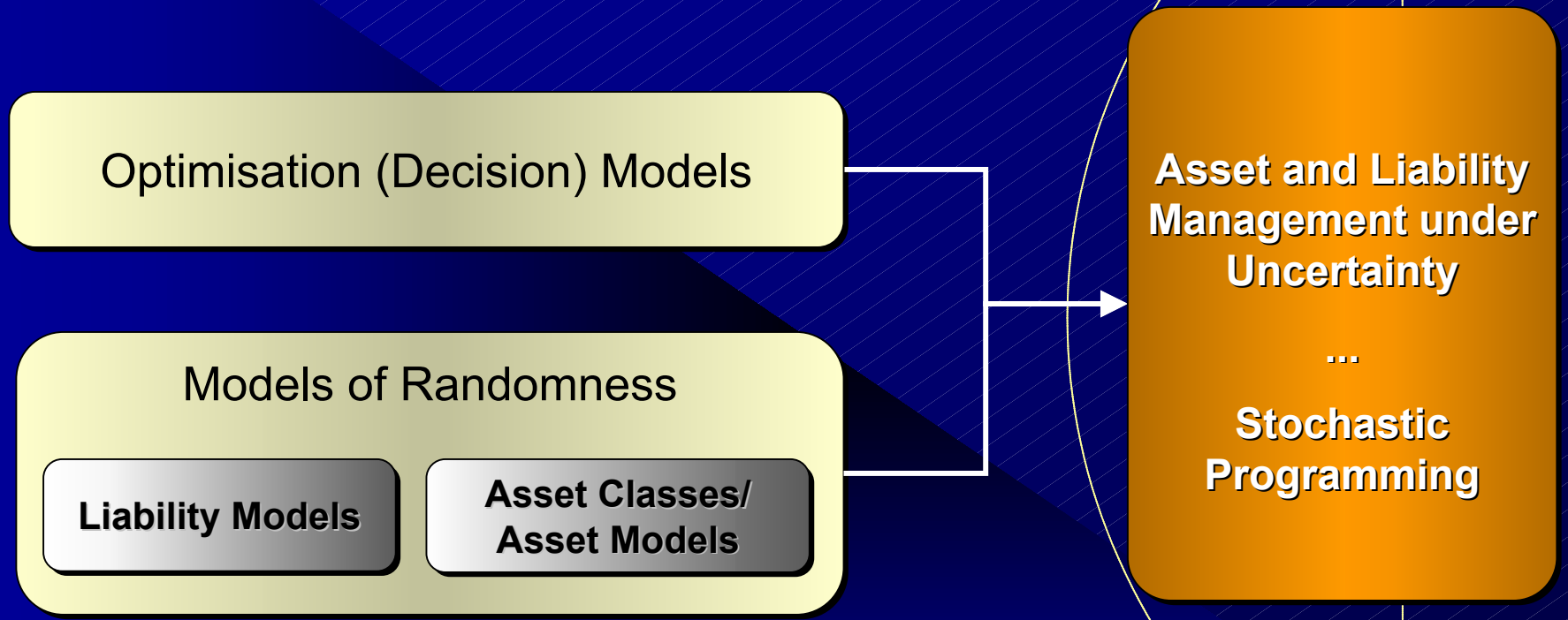
- Planning for the Future is synonymous to dealing with uncertainty.
- Optimisation (Linear/Integer Programming) models assume certain states of nature.
- Multi-time period of investment decisions.
- Decisions need to be made today, “Here and Now.”



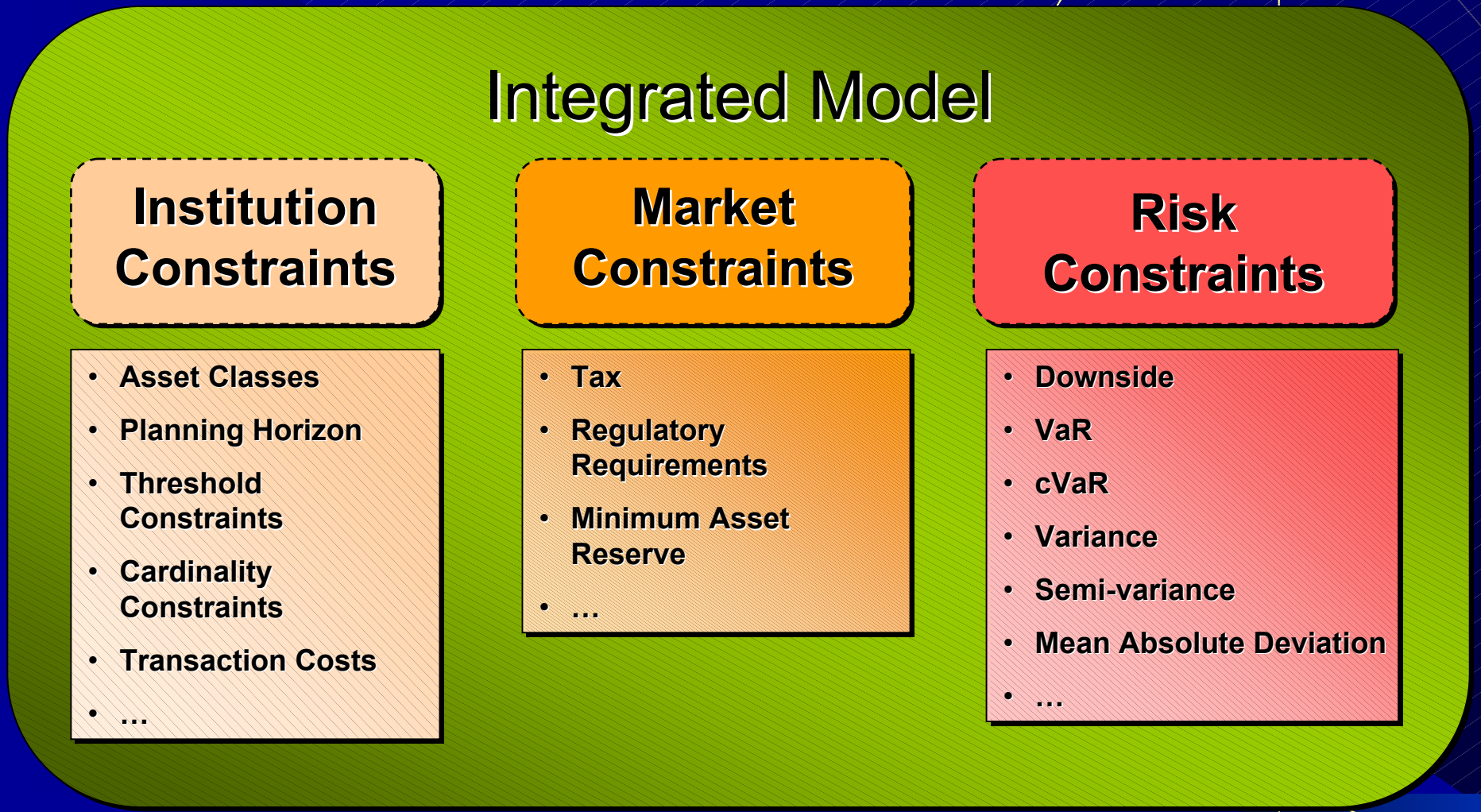
Stochastic Programming



ALM and SP Integration



Integrated Model Building



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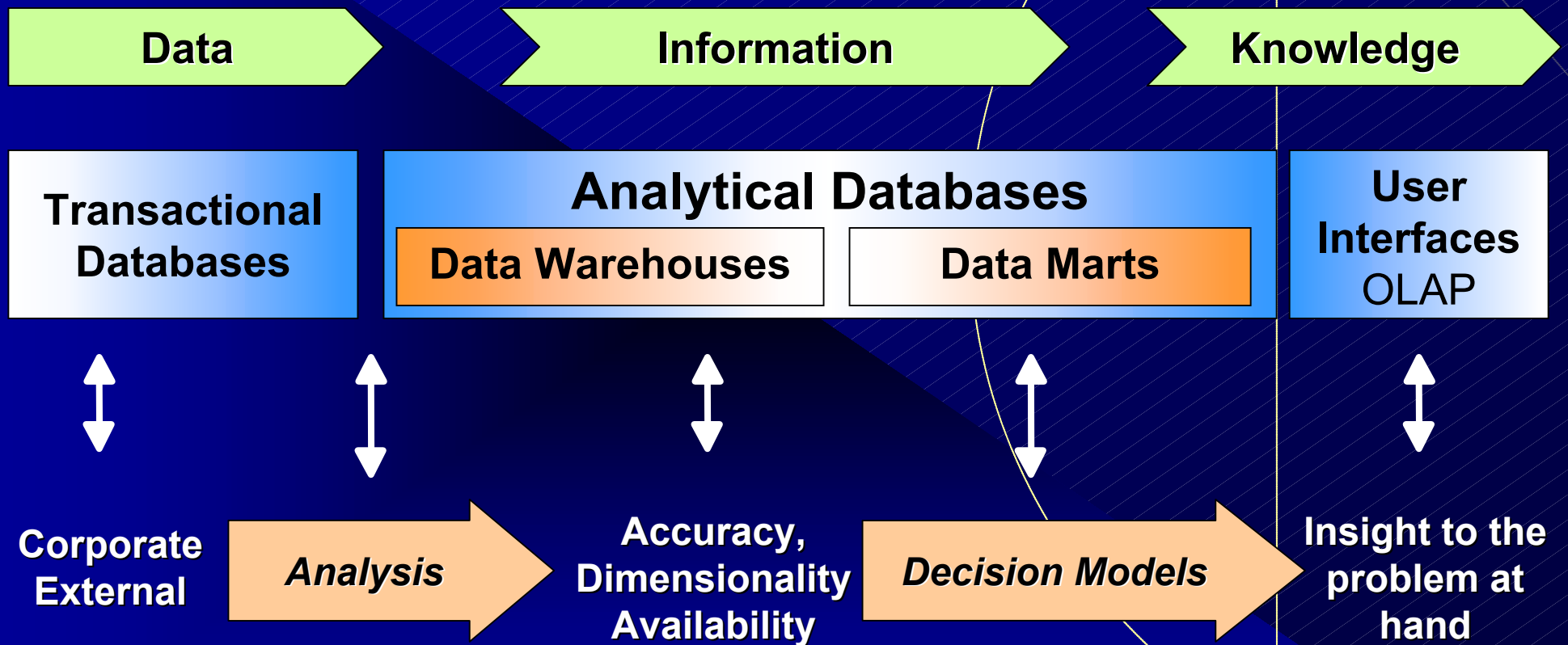
On-Line Analytical Processing

- With us since 1992
- Evolved into a User Interface feature for large data sets.
- Aimed for Analysts and Analytical models
- Highlights:
  - Multidimensional (therefore Realistic) Viewing of data
  - Hierarchical and Cross-Dimensional Data Operations (Roll-Up, Drill-Down, Slice, Dice)
- We use it for dynamic model instantiation
  - Feasibility of Models can be quickly investigated
  - Detailed results can be easily obtained
  - Sub-problems can be easily created

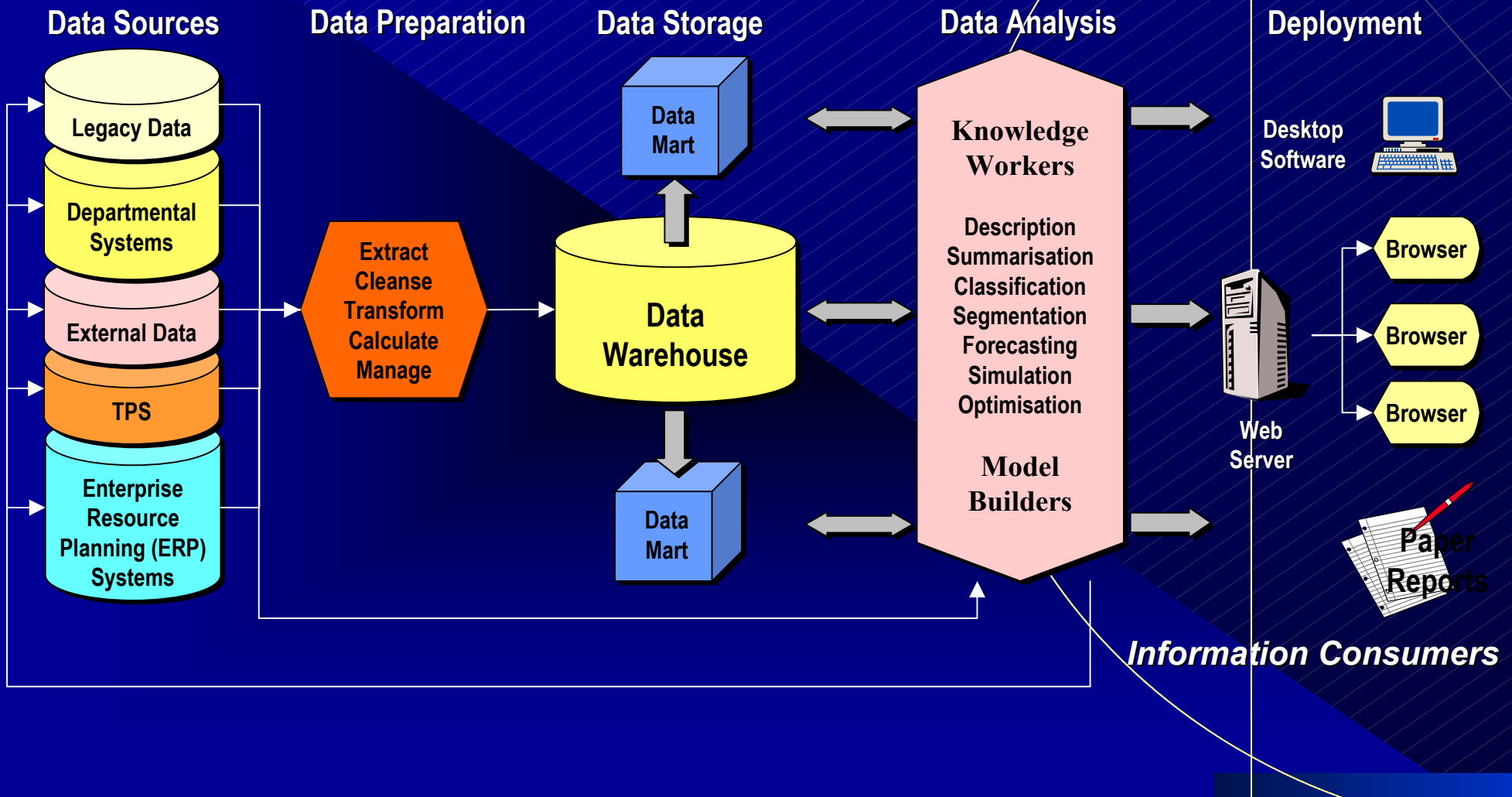
OLAP: how it fits in...

- OLAP evolved in parallel to Data marts and Data Warehouses
- Dimensional (data) modelling is common to all three:
  - Multidimensional user view of the world
  - Decisions and Business Analytics naturally view the world in terms of dimensions
- Mathematical Programming is naturally multidimensional (sets!)

Information Value Chain



The SPSS View :
"Analytical Solutions Framework"



OLAP Operations in Decision Models

- Roll-Up, Drill Down, and Slice fundamental for model instantiation
- **Roll-up:** Aggregated models - feasibility studies, strategic decisions (Typical aggregation by Σ, μ. Others are possible)
- **Drill-down:** Detailed models - tactical decisions
- **Slice:** Sub-models - investigate weighting of model components

OLAP Operations in Decision Models

- **Model Investigation**:
- Summarise, Detail, or Filter data before model Instantiation
  - Requires careful data preparation and database design (e.g. alternative summary functions may be required for model consistency)
  - May require dynamic changes in the model
  - Industry standard connectivity with OLAP tools is still limited [XML may change that…]. We use Relational OLAP Schemas for most of our work, and SQL for OLAP operations.

OLAP Operations in Decision Models

- **Data Analysis:**
- Summarise, Detail, or Filter data following model instantiation
  - Most typical use of OLAP (e.g. Pivot Tables)
  - Requires basic preparation at the data level
  - Pretty straight-forward to do (unless there are complex aggregation and cross dimensional rules)
  - Not really useful and does not achieve OLAP's full potential in Decision Support Systems / Business Analytics

OLAP for DSS: Pros and Cons

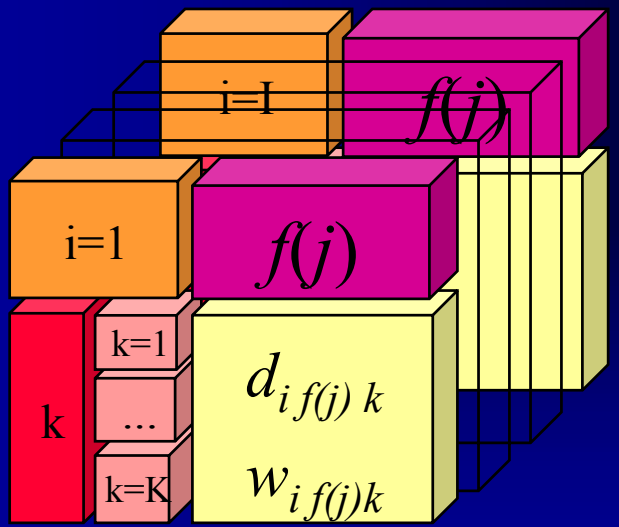
- Careful data and model preparation is necessary
- Results justify the preparation effort (in terms of using the DSS. Data values may not be as predicted/expected):
  - With few if any alterations the Data Mart drives the model investigation and/or data analysis
- High-level Dimensions can be used to store alternative data scenarios, and/or to drive alternative models

OLAP features in DSS Modelling

3 dimensions: $i, j, k.$ **2 Vectors:** $d_{ijk}, w_{ijk}.$ **Summary function:** $f(j)$

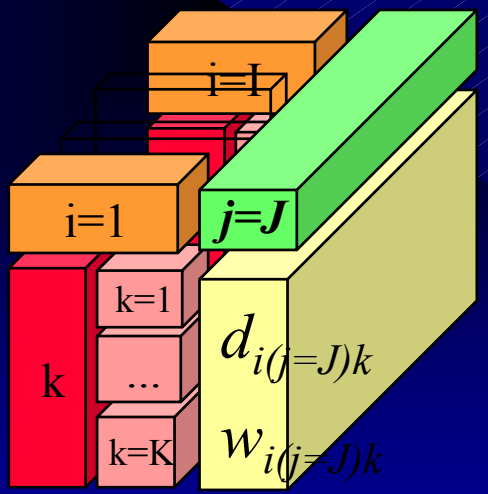
Summary Model

Roll Up over $j \equiv f(j)$



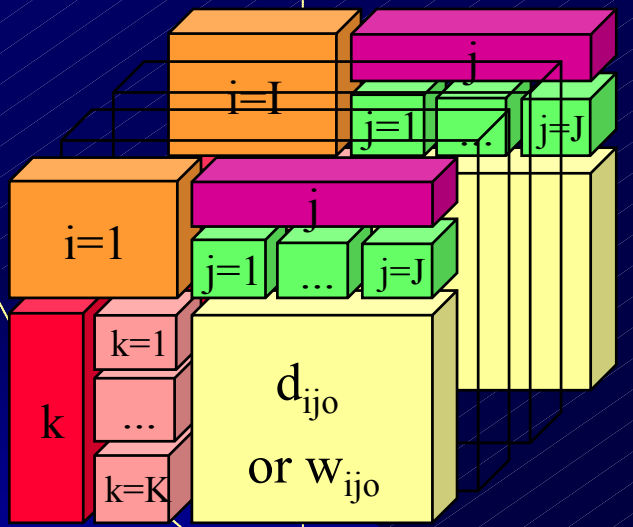
Sub-Model

Slice on $j, j=J$



Detail Model

Drill-Down on j



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Model Specification

- Planning Horizon: 12 months
- Initial Capital: $1,000,000
- Additional Income per rebalance: $10,000
- Rebalance Strategy: Twice at months 2 and 6
- Number of scenarios: 50
- Probability of occurrence: Uniform
- No liabilities (yet...)

Maximise

Terminal Wealth - $Risk_t$

Subject to:

Initial Holdings = 0

Wealth = investment * return

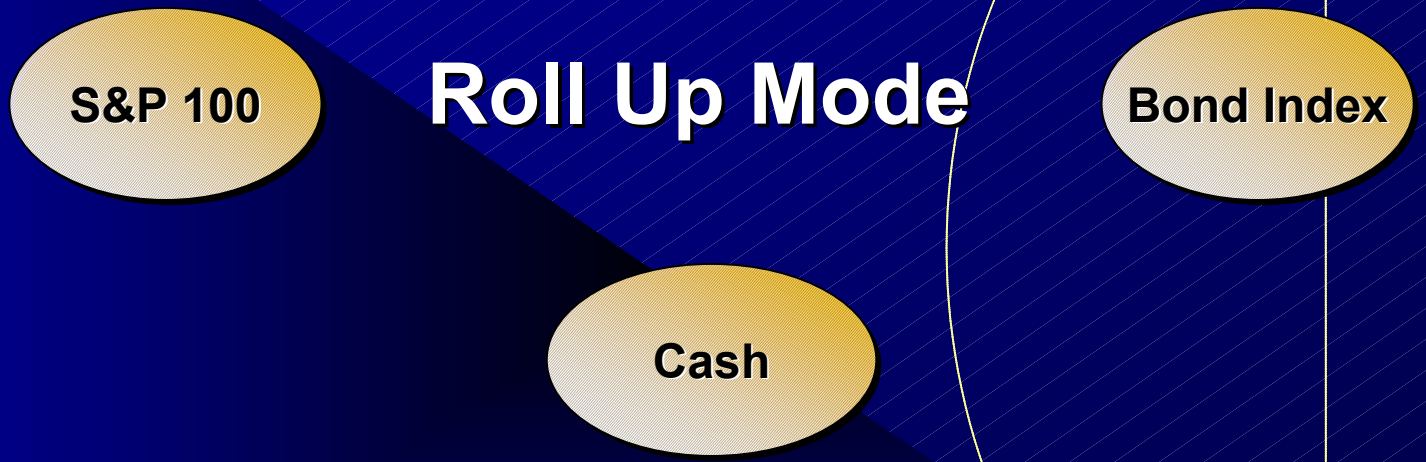
Fund balance constraint

Asset holding constraint

Transaction costs

Downside Risk *(Medium and Medium/High Risk Profiles)*

Model Specification – Asset Universe



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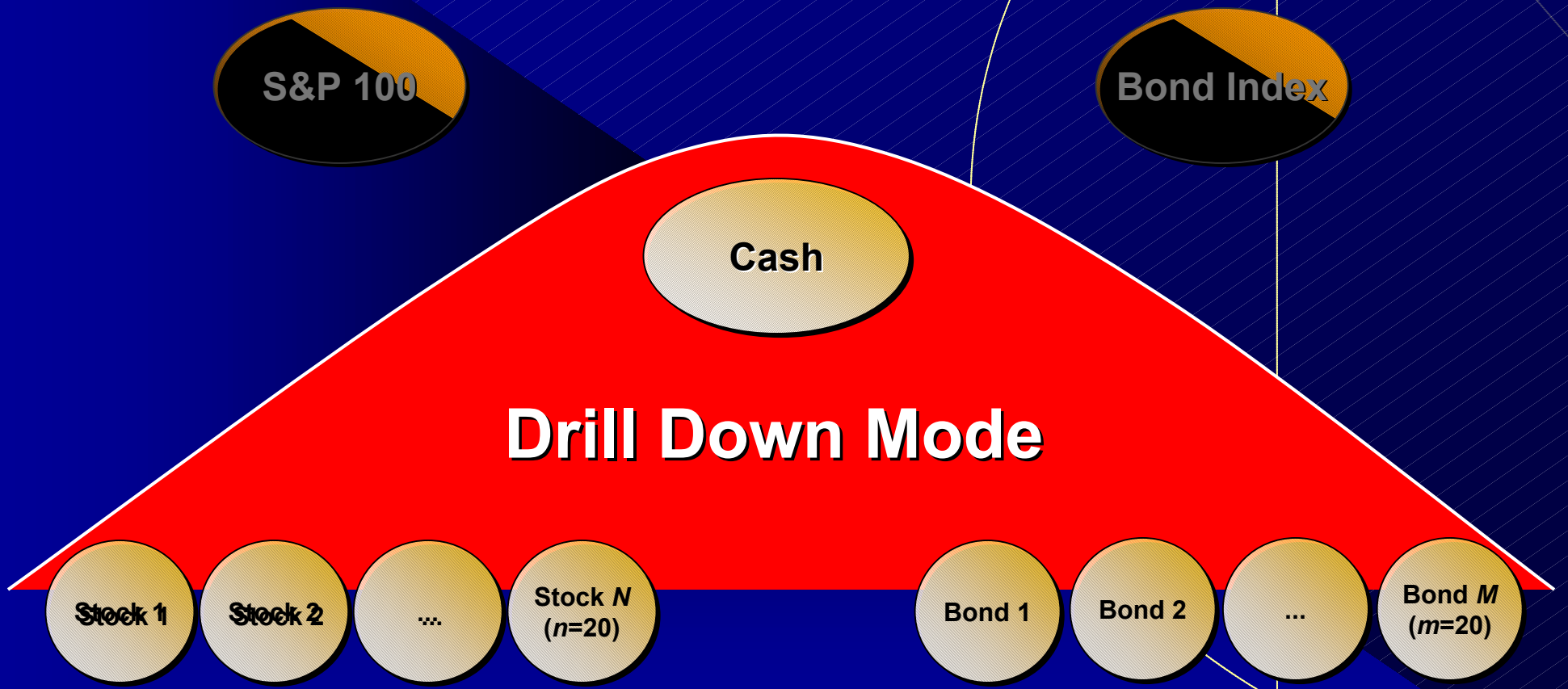

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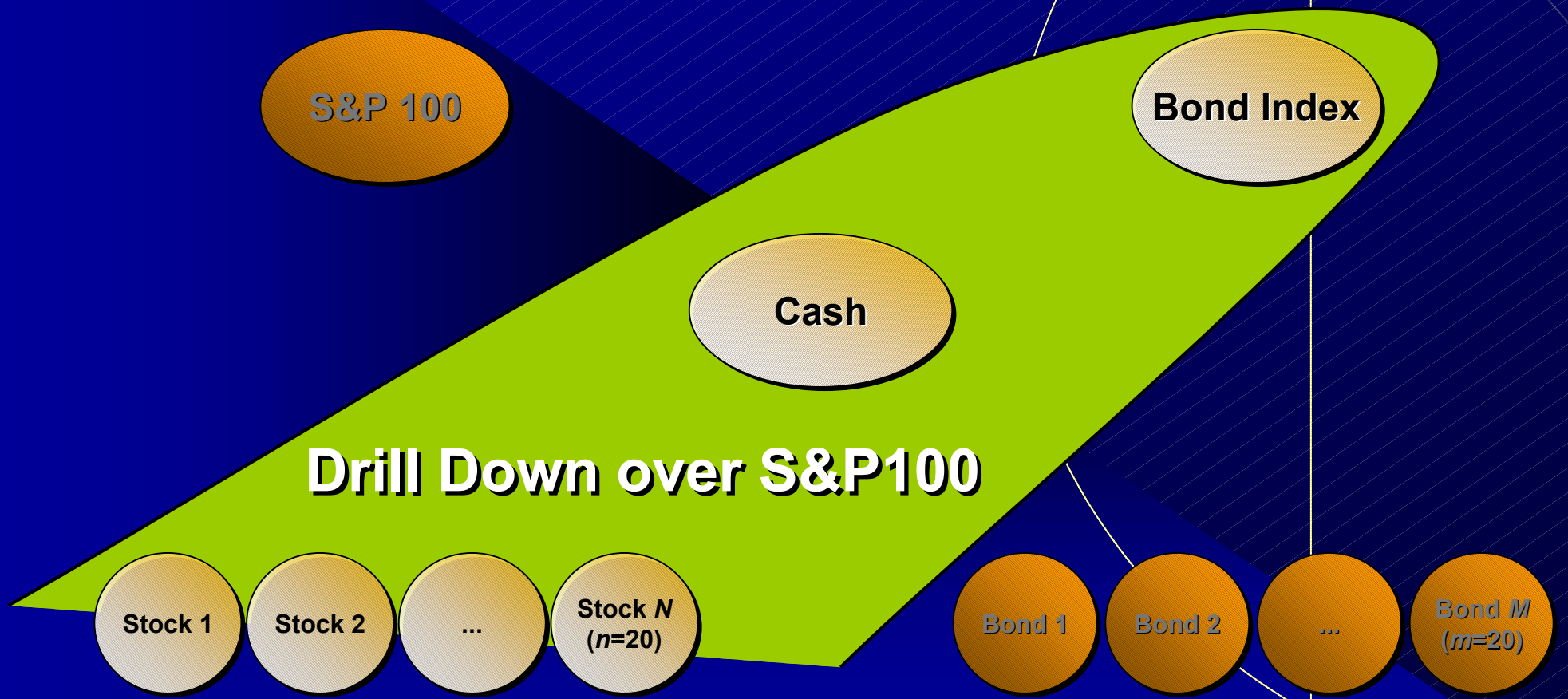

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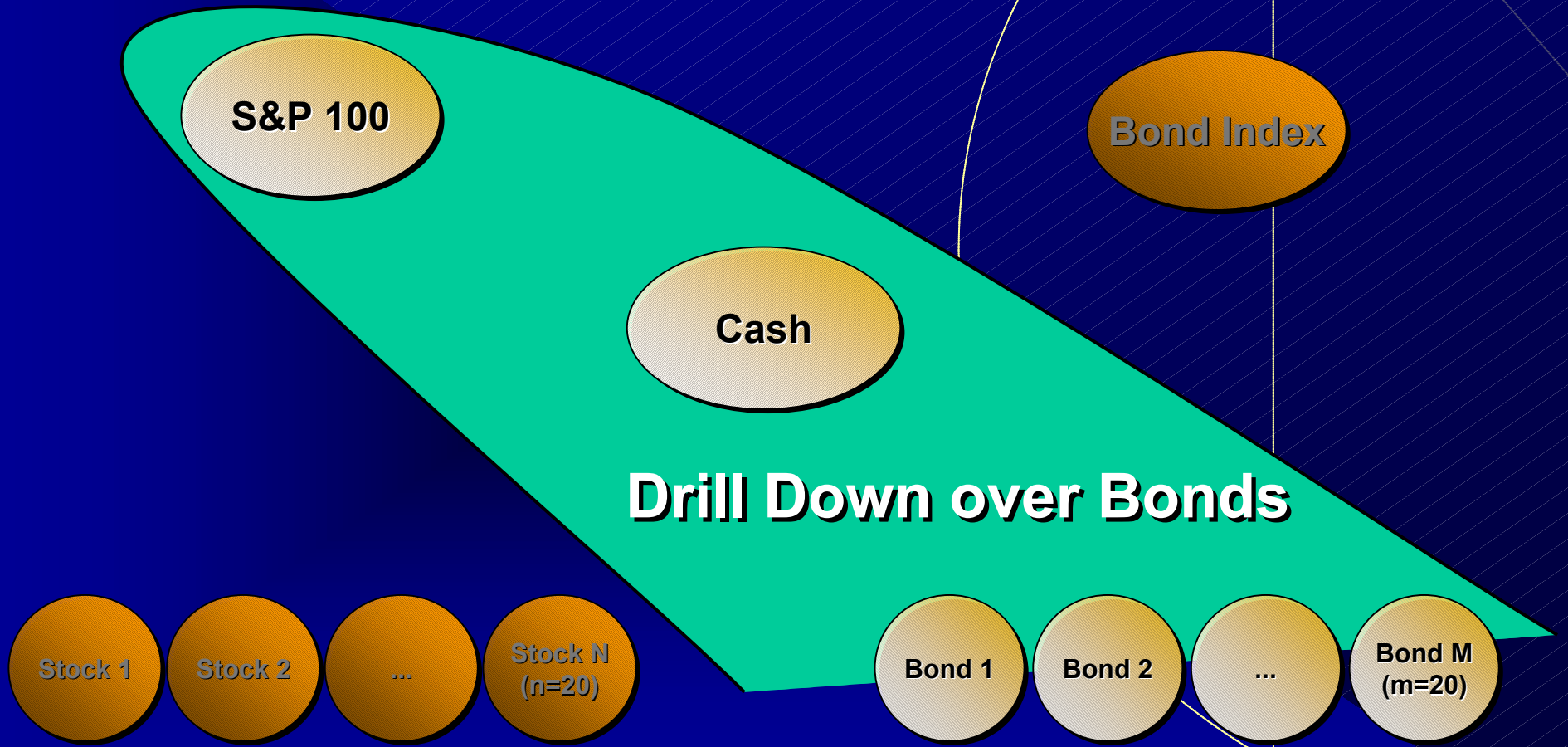
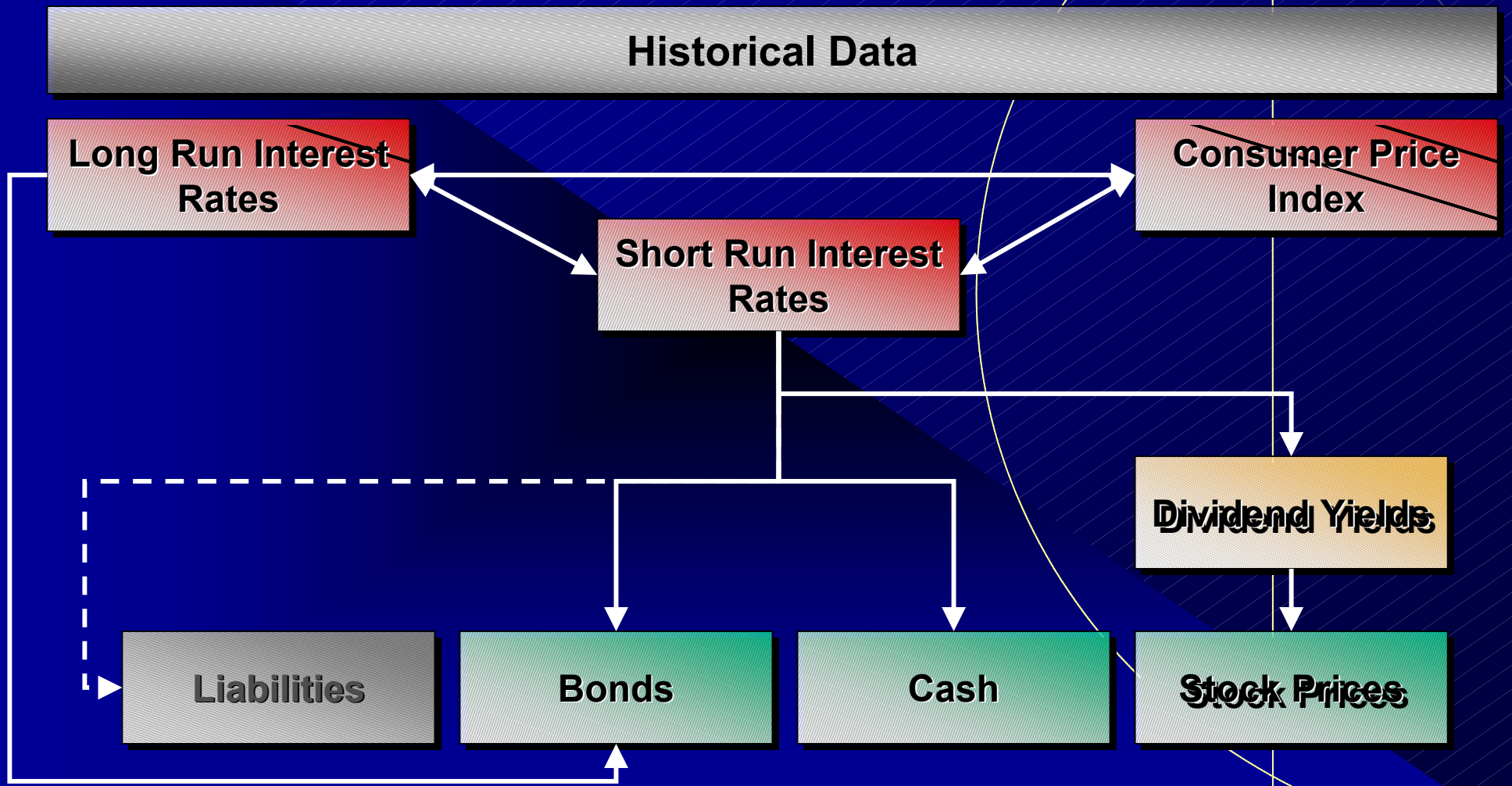
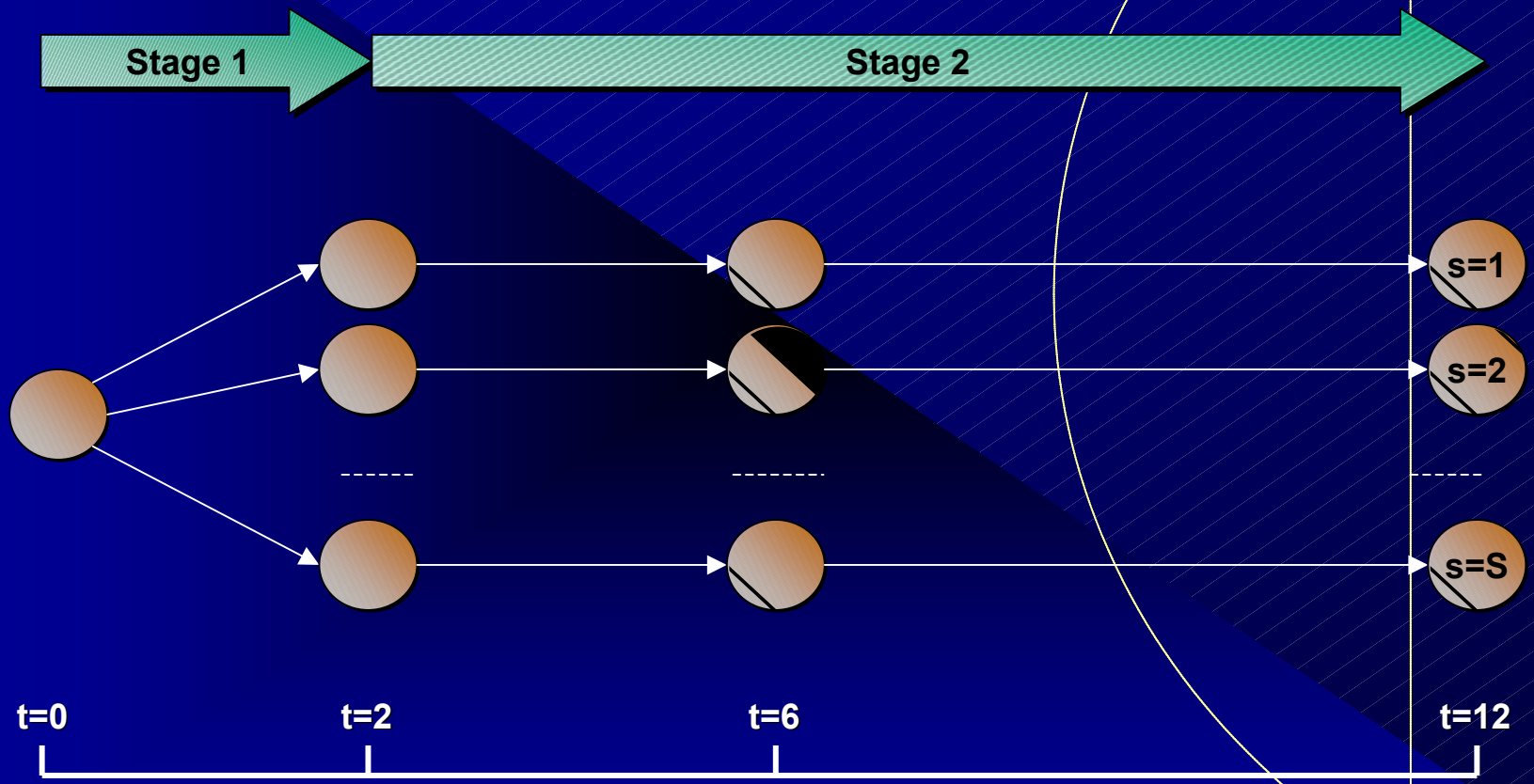


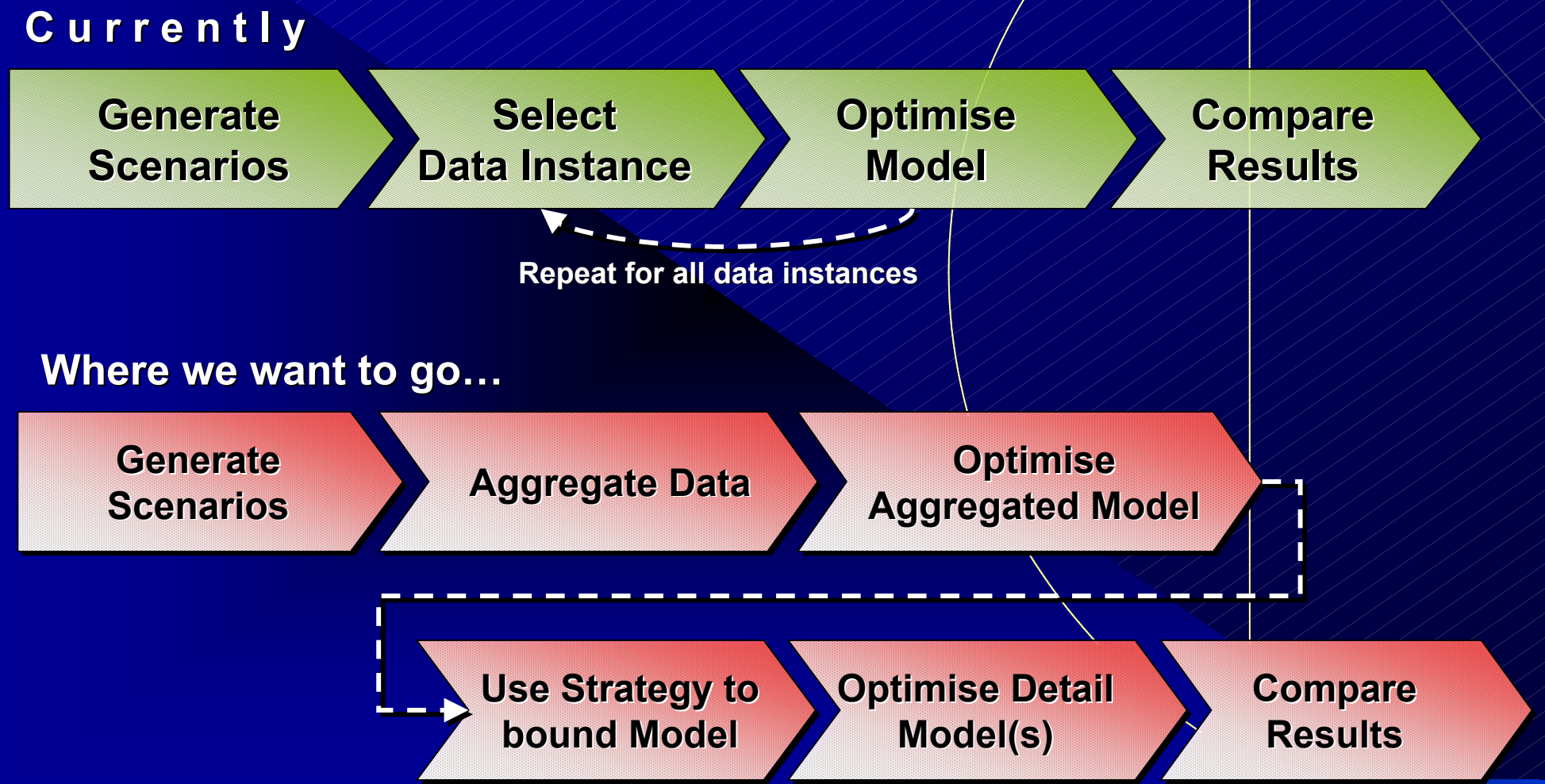
An Integrated Scenario Generation System



2-stage Stochastic Tree



Our investigation



Formulation and Solving Strategy

- 1 Generic Model - 4 data instances:
  - Roll-Up Model: 3 Asset Classes
  - Semi-Drill-Down Models:
    - 20 Stocks + 1 Bond Index + Cash Investments
    - 1 Index (S&P100) + 5 Bonds + Cash Investments
  - Drill-Down Model:
    - 20 Stocks + 5 Bonds + Cash Investments

Work in progress, 3 challenges:

Scenario Generation
SP, Risk, and ALM Modelling
OLAP Integration

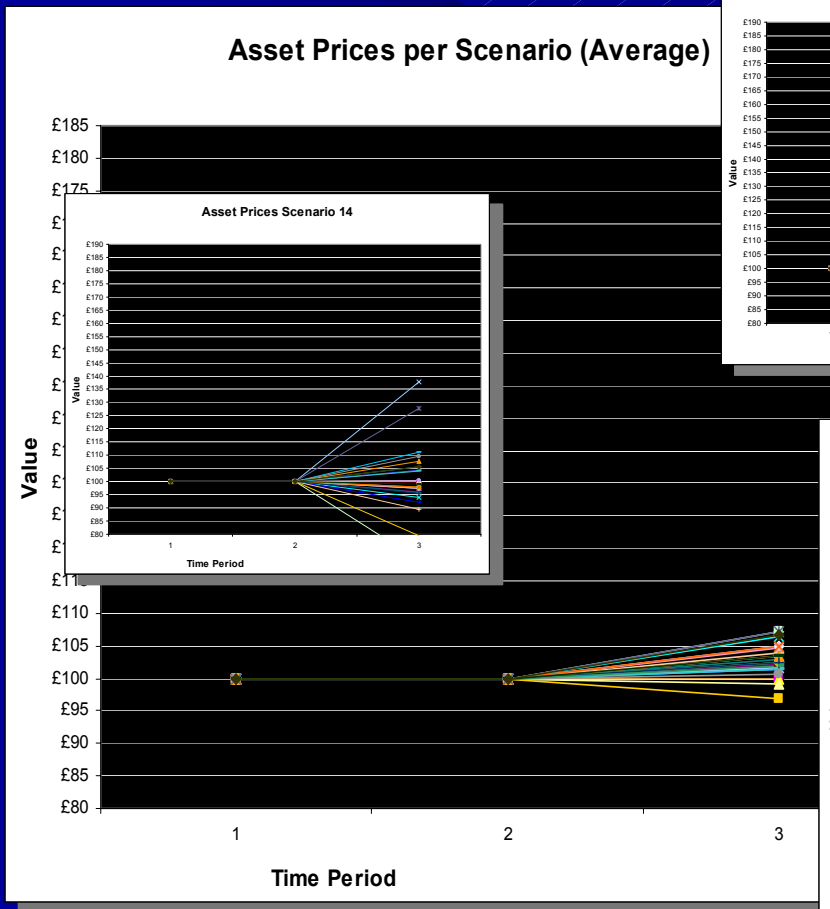
Currently:

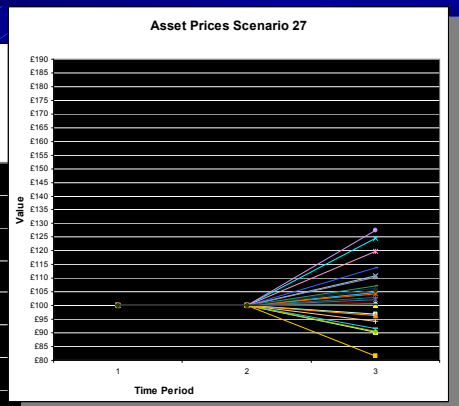
Scenario Generation
Model Formulation

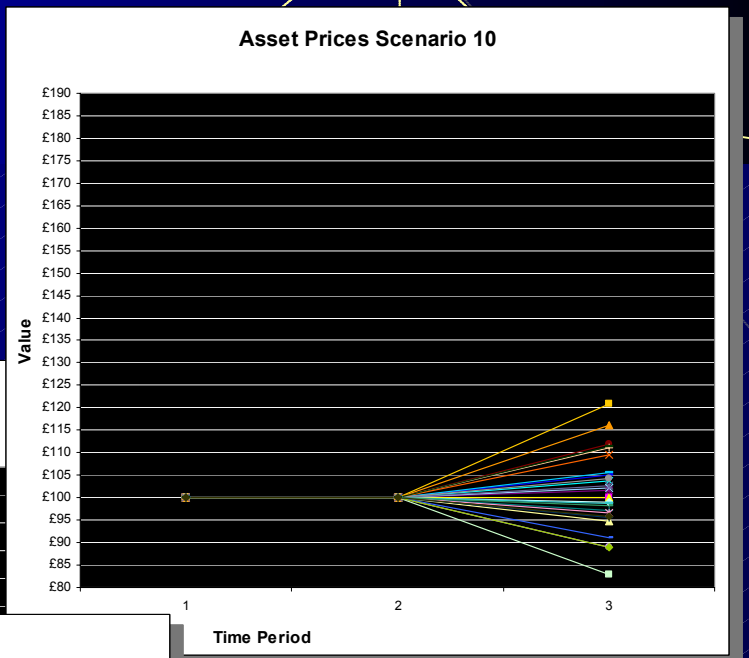
Upcoming:

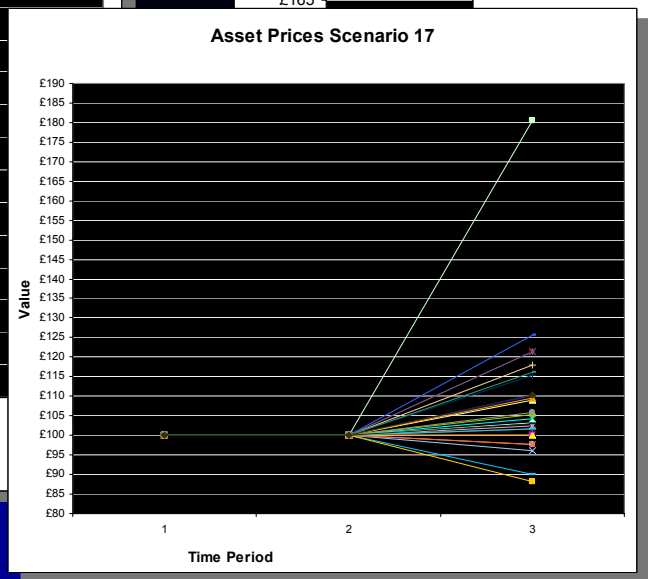
OLAP Integration
…

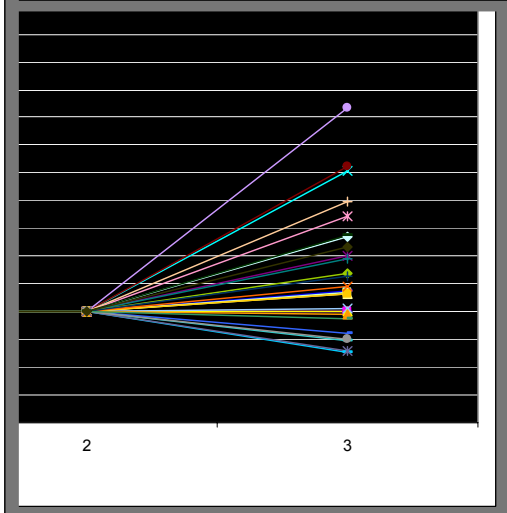
Sample Scenarios











Results so far...

- When Stocks are drilled-down, they constitute 100% of the portfolio.
- Stocks are the best investment for the risk-friendly investor.
- Results are comparable between Asset Classes and Drill-down over Bonds.
- Few bonds and cash for less-risky investors.
- Bonds and Cash are selected only when stocks are rolled up
- These results are specific to the scenarios generated (non-normally distributed)

Medium Risk Profile

Medium Risk	Roll Up	Roll Up	Roll Up
Asset Class	*today*	*month 2*	*month 6*
Stocks	44.00%	47.91%	46.06%
Cash	18.00%	22.14%	32.61%
Bonds	38.00%	29.95%	21.34%
Expected Wealth	£1,041,271.72	£1,095,642.21	£1,162,536.77
Medium Risk	**Bonds DD**	**Bonds DD**	**Bonds DD**
Asset Class	*today*	*month 2*	*month 6*
Stocks	36.00%	38.07%	40.22%
Cash	18.00%	24.26%	23.07%
Bonds	46.00%	37.66%	36.72%
Expected Wealth	£1,054,792.60	£1,118,297.23	£1,197,487.57

Medium/High Risk Profile

Medium/High Risk	Roll Up	Roll Up	Roll Up
Asset Class	*today*	*month 2*	*month 6*
Stocks	43.62%	44.16%	43.68%
Cash	21.68%	24.91%	30.19%
Bonds	34.70%	30.93%	26.13%
Expected Wealth	£1,033,833.99	£1,072,346.63	£1,118,990.73
Medium/High Risk	Bonds DD	Bonds DD	Bonds DD
Asset Class	*today*	*month 2*	*month 6*
Stocks	31.66%	31.63%	33.11%
Cash	24.62%	29.42%	23.04%
Bonds	43.72%	38.95%	43.85%
Expected Wealth	£1,036,978.72	£1,081,572.85	£1,131,287.28

Forthcoming Challenges

- Use OLAP techniques to fix the strategy on tactical decisions, with dynamic model readjustment (e.g. bounds may be necessary, etc.)
- Determine threshold risk profiles for investor
- Backtesting
- Fine-tune Scenario Generation