Planes, Trains, Automobiles ....

A System Dynamics Model
with Discrete Elements

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Overview

- **Model developed for Canadian Dept National Defence to review impacts of potential Millennium Bug failures on their ability to undertake International Operations**

- **Situation contained features that were continuous in nature and others that were discrete**

- **SD model developed that contained a number of discrete elements**

- **This presentation describes and reviews the model, particularly concentrating on the continuous and discrete features**

International Operations Model

- **A single model to represent a number of scenarios**

- **Scenarios set up through data**

- **Model is activity-based not (IT) System-based**

- **Architecture involves:**
  - Access Database - IT and Platform System performance levels, and System Packages to perform specific activities
  - Excel Spreadsheet - user interface
  - Powersim - SD model

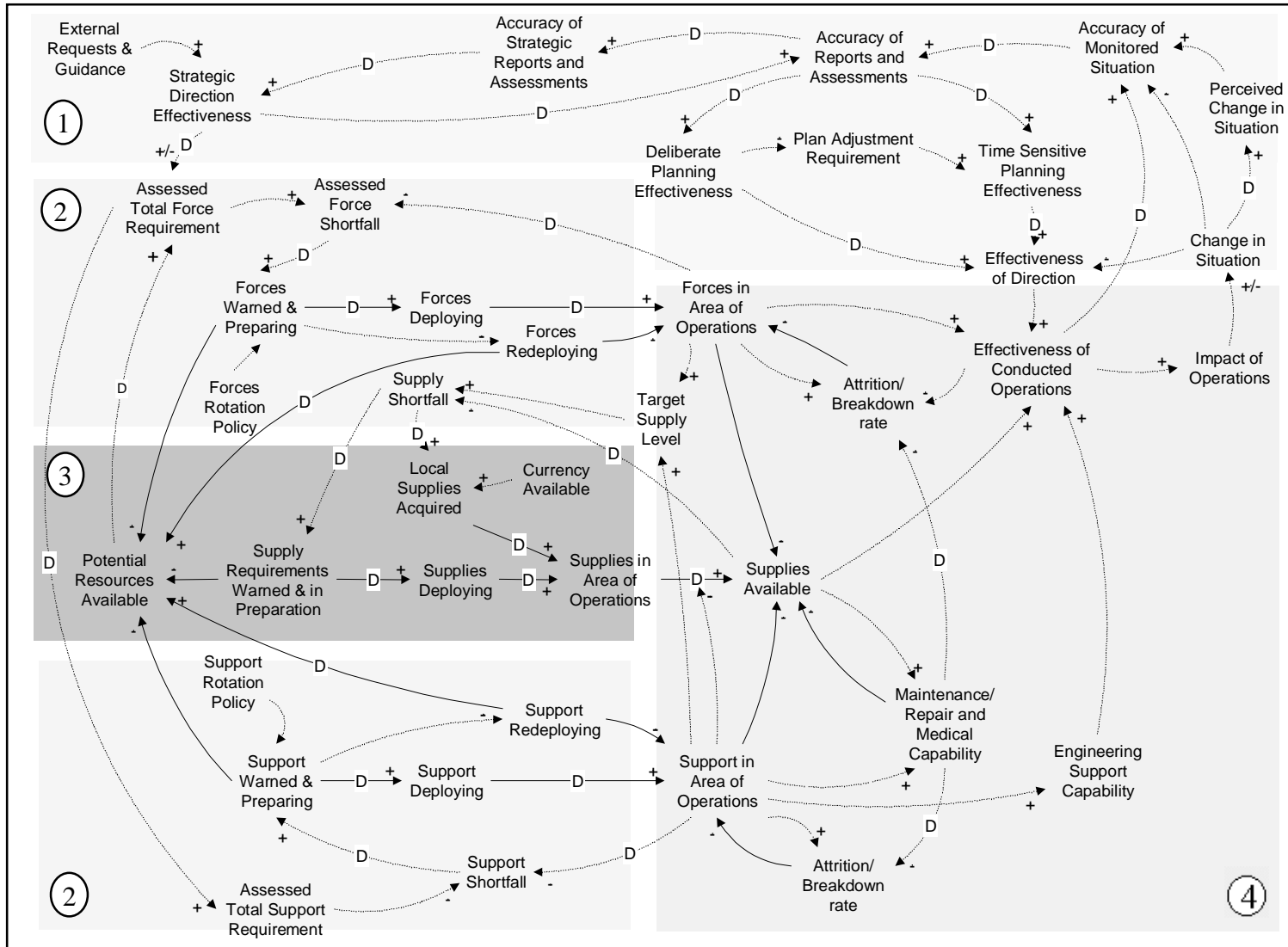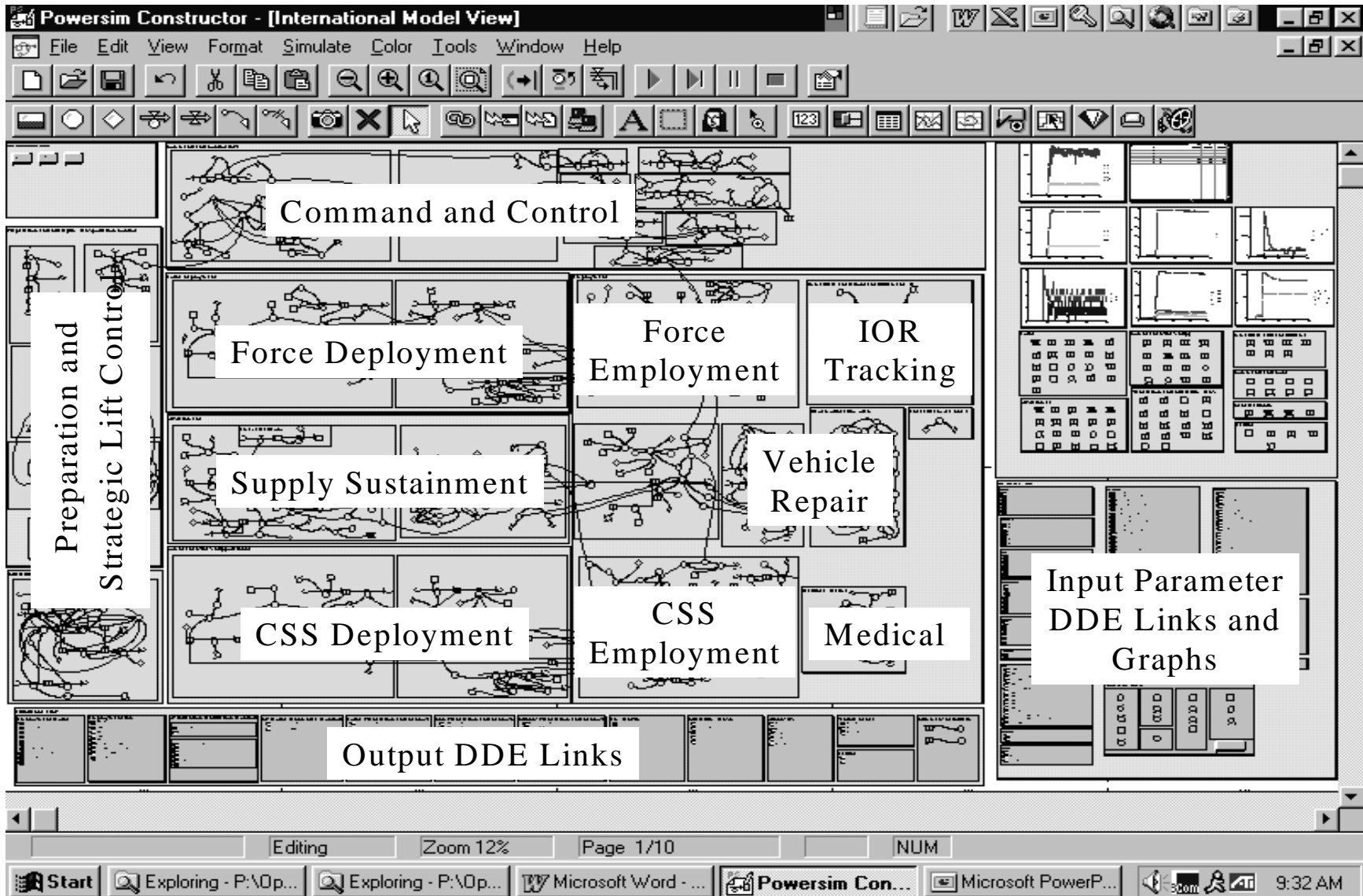# Overview of Model
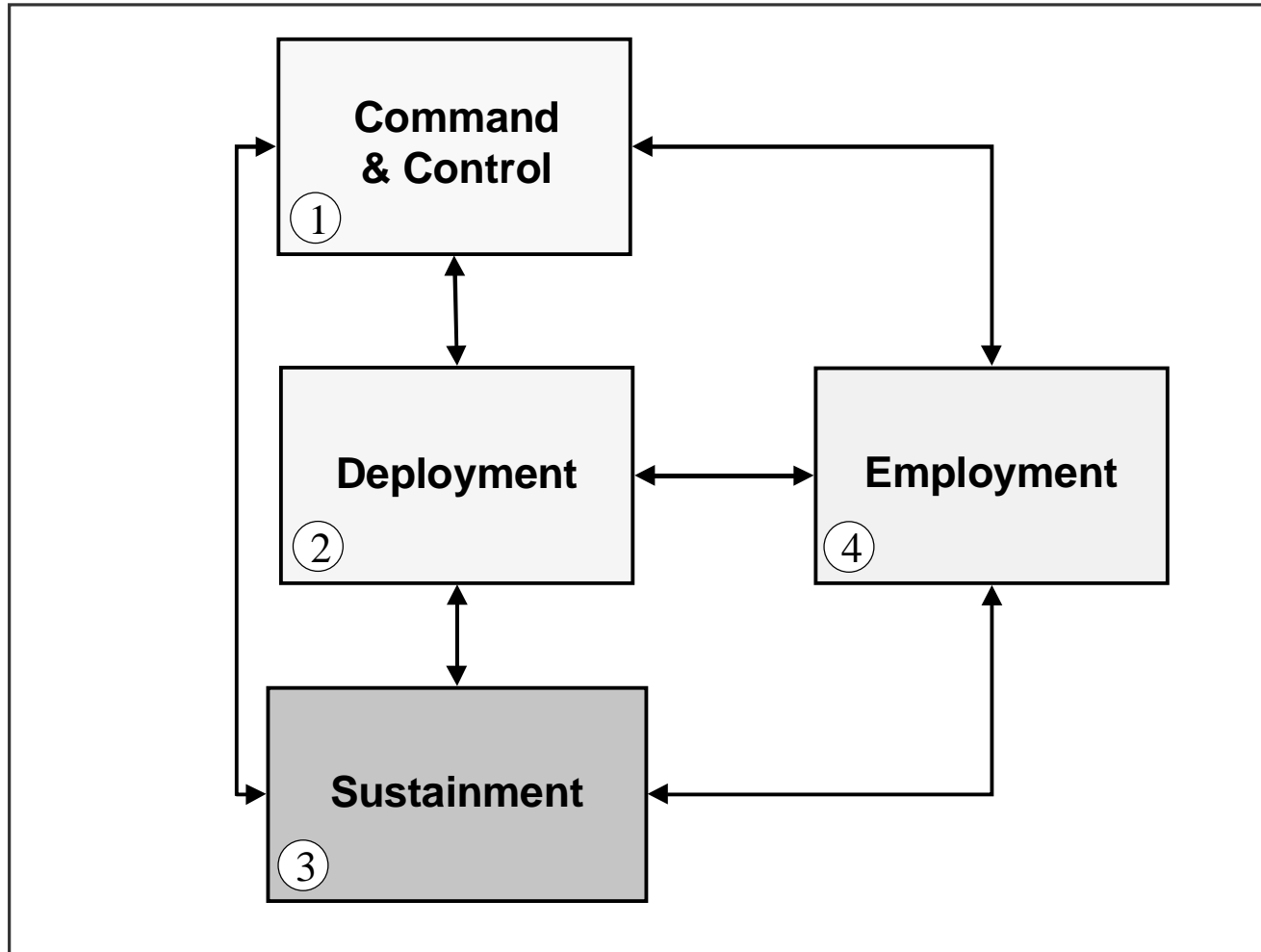
High Level Influence Diagram

The Stock-Flow Diagram

Main Model Elements

- ## Mission Phases
  - Recce, Vanguard, Main Deployment, Employment, Rotation

- ## Forces
  - Personnel, Light Vehicles, Heavy Vehicles, F18s, Ships, Sea Kings

- ## Support
  - CSS Personnel, CSS Medical, CSS Heavy, CSS Light

- ## Supplies
  - Canadian Supplies, Local Supplies, Vehicle Spares, Air Spares, Sea King Spares, Fuel, Medical Supplies

- ## Strategic Transport
  - Air Courier, Commercal Air Scheduled, Commercial Air Charter, CF Airbus, CF Hercules, CF Challenger, Container Ship, Air Self, Sea Self, (Railway, Road, Trailer, Road Self)

SD Features of Model(s)

- **Large-scale model - wide scope**

- **Long durations**
  - **International model - up to 2 years, 1/2 day timestep**
  - **National model - up to 5 weeks, 1/2 hour timestep**

- **Large number of entities in some classes**
  - **International model - forces/support 750 - 2000 entities (up to double during rotation), supplies 10 - 500 $\times$ force size**
  - **National model - forces/support 1000 - 50000 entities, supplies up to 50 $\times$ force size**

SD Features of Model(s)

- Force/supplies shortfall correction mechanisms
- Communications/perception delays
- Transit times (in Theatre) - exponential delays
- National model strategic transit times - exponential delays
- Command & Control (situational awareness)
- Loss of force effectiveness through supply shortages (ratio of supplies to forces + conversion graph)

Discrete Features of Model(s)

- **Small number of entities in some classes (particularly ships, Sea Kings and Aircraft, also strategic transport assets)**

- **Scheduled force preparation times**

- **Mass strategic transport (interaction of force/supplies and strategic transport assets)**

- **Tracking of immediate operational requirements & impacts on vehicle repairs**

- **Variation in attrition rates, supply usage, breakdown rates**

Implementing Discrete Elements

- **High degree of arraying**

- **Maintain discrete numbers of (most) class entities in key levels**
  - **force preparation done in groups (by operation phase) using pipeline delays**
  - **flow rate calculations ensure flow of whole units**
  - **complex interface between strategic transport units and entities to be moved**
  - **complex vehicle repair structure, matching repair capacity and parts availability**

- **Co-flows to closely track or control special cases**

- **Casualty/breakdown/supply usage multiplier graphs**

Migration from Classical SD

- Strategic/Conceptual Level
- Deterministic
- Physical/Information Flows
- Exponential Delays
- Indistinct Entities
- Flow Control Mechanisms
- Understanding Feedback Dynamics
- Long-term Behaviour
- Simulate in Equal Time-steps

- More Operational - Increased Detail

- Pipeline Delays
- Increased Entity Classes (Arrays)
- Holding Mechanisms
- Understanding Performance Over Time
- Shorter-term Behaviour

SD   **Discrete Event**