N93-26990

GPS Sytem Simulation Methodology

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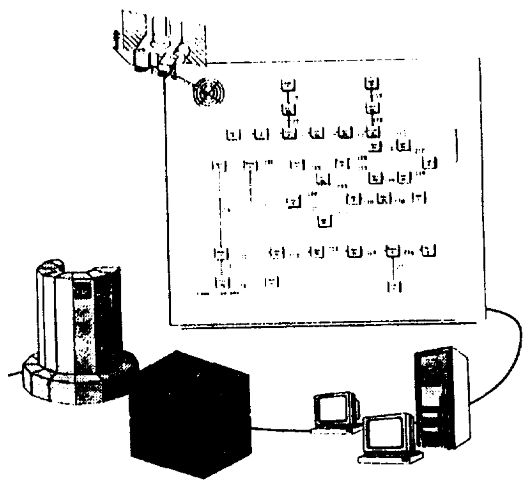

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Talk Outline

- Background
- GPS Methodology Overview
- Graphical User Interface
- Current models
- Application to Space Nuclear Power/Propulsion
- Interfacing requirements

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History

- SALT (system analysis language translator) - Early 80's
  - PL/1 code for IBM mainframes
  - Moved to multiple platforms and languages (C, C++)
  - Batch oriented - translate, compile, run
  - Used model and property libraries
  - Optimizations and system analysis

  Applied to

  - Open-cycle and liquid-metal MHD systems
  - Fuel cells
  - Ocean thermal energy conversion
  - Municipal solid waste processing
  - Fusion
  - Breeder reactors
  - Geothermal and solar energy systems

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Next Generation Implementation - GPS

- Designed for modern workstation environments
- Developed in C++, moved to C for greater portability
- Steady-state & dynamic model libraries concept of SALT, but accessed as *class objects*
- Complete, extensible, object-oriented control language with numerous procedures for optimizations, equations solving, system constraints, parametric analysis
- Language interpreted, but uses compiled, fully optimized models and math procedures ==>
  - Fast prototyping cycles
  - On-the-fly creation of/interaction with simulations
  - Simulation systems can be interupted, queried and changed, then resumed

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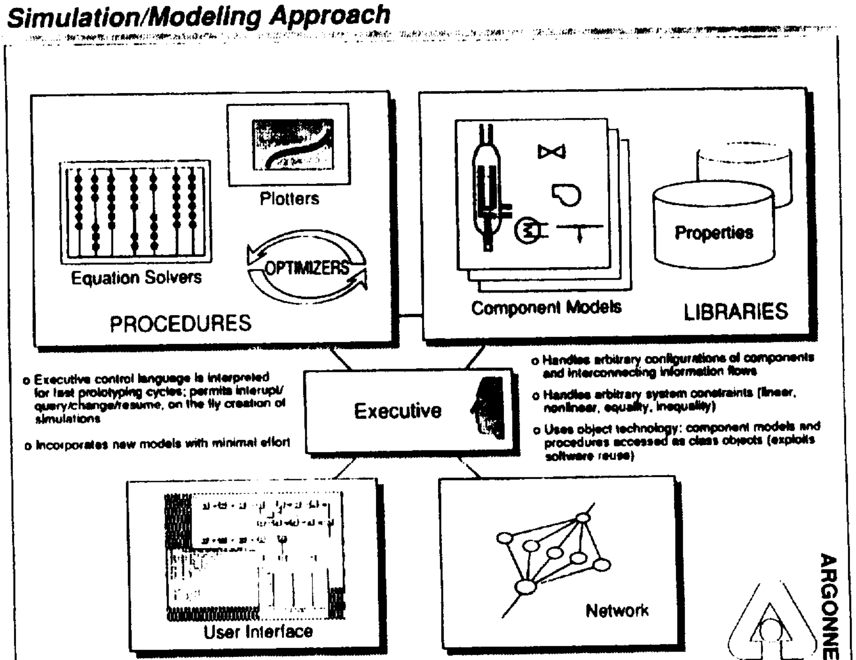
Simulation/Modeling Approach



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GPS Operators

- 86 built-in operators
- I/O functions (fopen, printf, sscanf, sprintf)
- Math functions (atan2, pow, exp, max, ln, log10)
- Numerical procedures (vary, cons, icons, mini, diff)
- Looping and flow control

  cond {...} if

  cond {...} {...} ifelse

  start inc bound {...} for

  count {...} repeat

  {...} loop

  {cond} {...} while

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Miscellaneous Operators

- Allocate new model class instance - **cdef**

  /pump1 { pump: /param1 12.0 /param2 0.495 } cdef
- Set a debug level (0 thru 5) - **debug**
- Run gps simulation from a input file - **run**

  "input.fil" run
- Interrupt simulation to permit queries/interactions

  sintrp (followed by **resume** to continue)

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GPS Steady-State Power System Models

Basic component models

gas - gas flow initiator
sp - gas flow splitter
mx - gas flow mixer
ht - gas flow heater/cooler
hx - gas flow heat exchanger
cp - compressor
gt - gas turbine
pump - pump
df - diffuser
nz - nozzle
power - calculate system powers

Basic thermionic models

reac - reactor model
ti - thermionic converter
rad - thermal radiator
sp - power flow splitter
res - electrical resistor
bc - boost converter
bus - electrical bus
mass - mass calculations

More sophisticated models

therm - thermal flow initiator
hprad - heat pipe radiator
tds - thermionic diode subsystem
shx - simple, multinode heat exchanger
nhx - multinode, general purpose HT model

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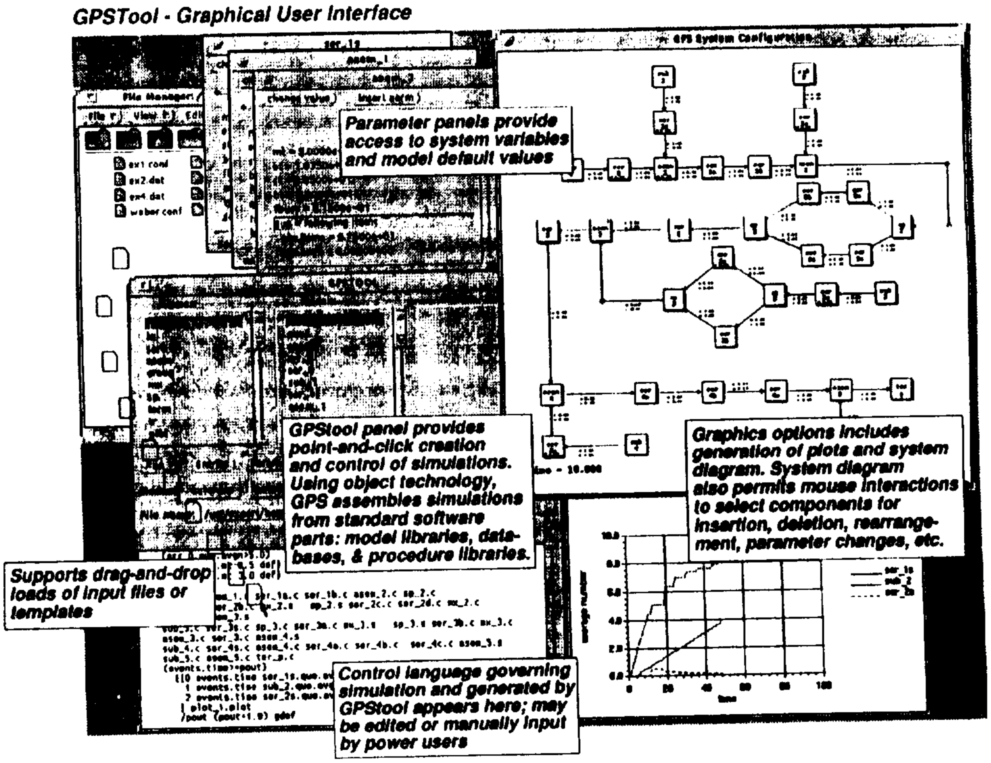
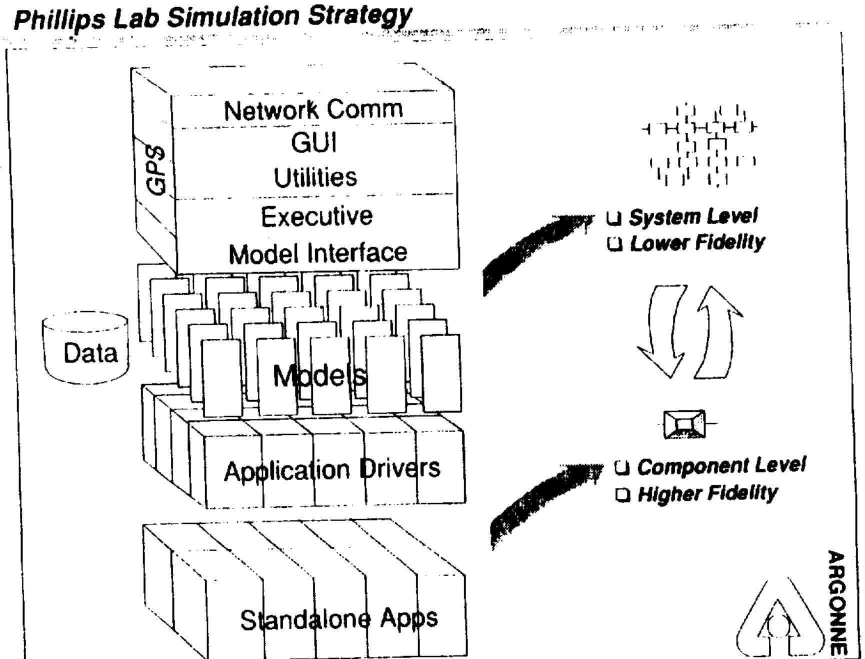
GPSTool - Graphical User Interface



Phillips Lab Simulation Strategy



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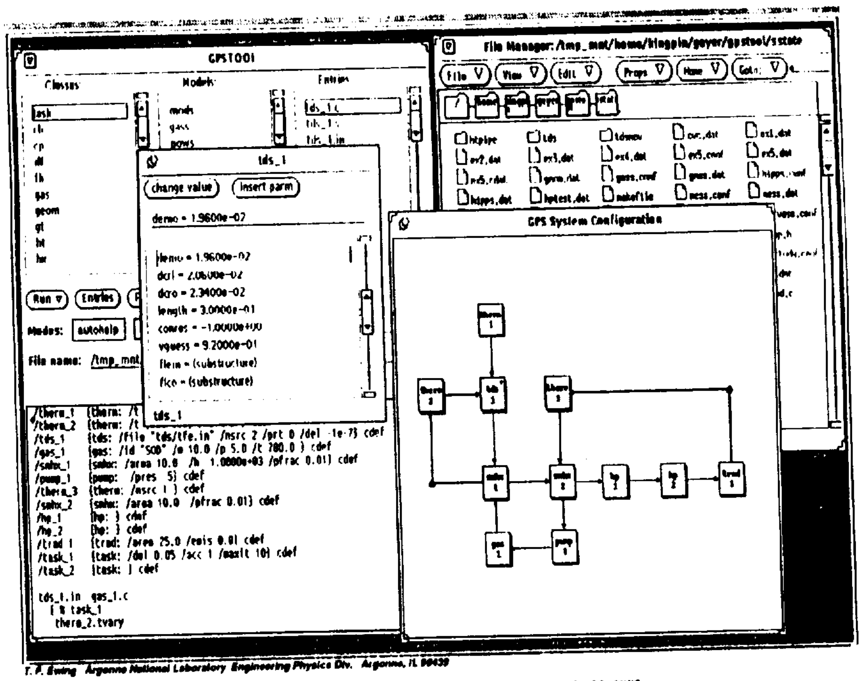

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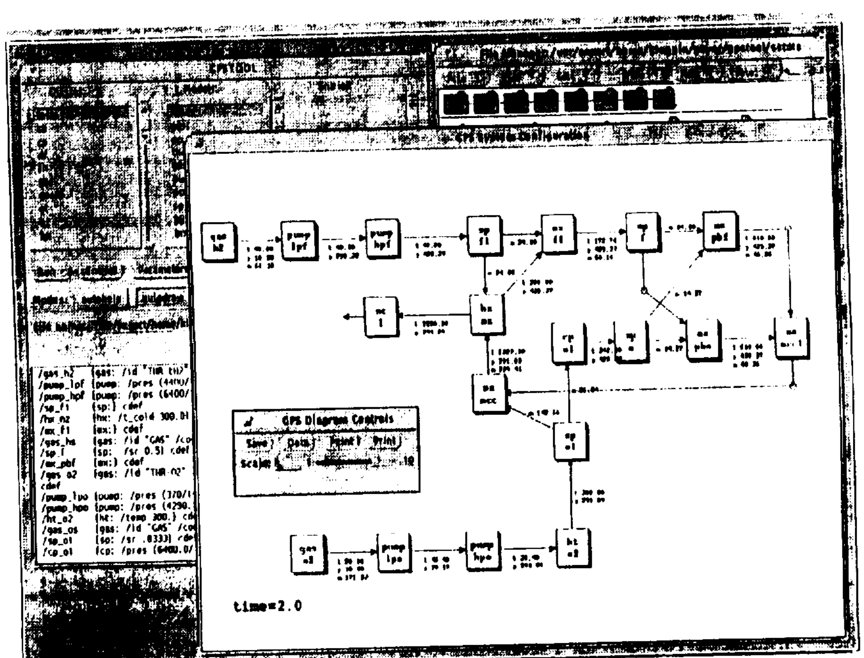

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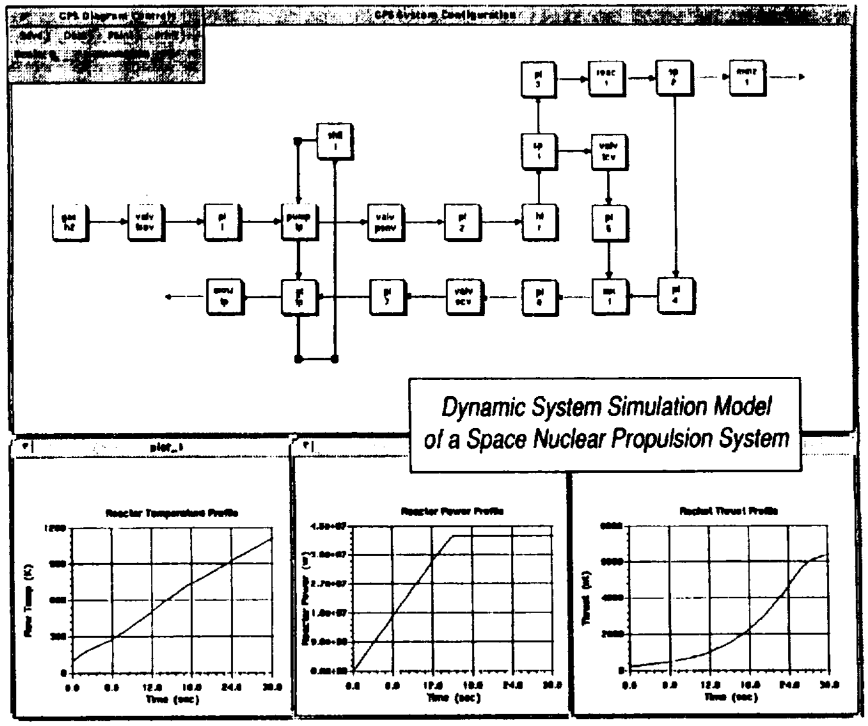
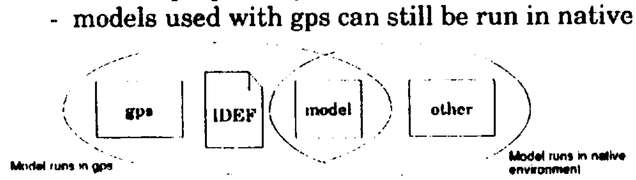


Dynamic System Simulation Model of a Space Nuclear Propulsion System

Advantages as Integrating Environment

- Consistent user interface to models
- Diverse models can be combined for use in arbitrarily complex systems
- Suite of gps system analysis capabilities (sweeps, optimizations) and numerical methods/properties available to models
- Interface definitions external to models ==>
  - can adapt models developed independent of gps
  - can use proprietary models available only as object code
  - models used with gps can still be run in native mode



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Interfacing Considerations

- Component models can be Fortran, C, or other Sun languages which generate linkable object code
- Standalone codes must be structured as subroutines with argument list of variables/parameters that must be known to GPS system
- Use of Fortran common blocks prevents (presently) having multiple instances of that model in a system
- Because models may be cycled through numerous convergence iterations with perturbed input flows

  Models must be true functions of their inputs

  Models must be reasonably robust

  I/O routines should be moved outside computation routines

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Converting a standalone code

- Two step process:

  Convert code to one or more subroutines

  Create a interface definition file (IDEF)
- GPS uses IDEF to generate small C code to handle interfaces
- Model can still be run independently of gps (standalone) by writing a main program to call subroutine

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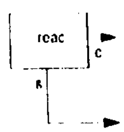
Interface Specification File Format

Interface specifications external to models

- User-prepared ASCII file used by GPS preprocessor to generate C stub code to handle gps interfacing
  - Model name
  - Variable types and initial values (arguments + gps I/O)
  - Entry procedures (name, arguments if Fortran routine, in and out flow variables)
  - Print variables (used as default gps output)

EXAMPLE
Thermionic reac model



c - mass/sizing, thermionic component of power

s - waste heat flow

```
model     reac
 char     names[16] namess[16] namers[16] nameboom[16]
 double   pow = 1e6 eff = 0.13 radius height sep = 10.0 rhoboom = 10.0
          lboom radiusrs volrs heightrs = 0.37
 flowtype ll lls
 masstype mcore mss mrs mboom

entry     c
 outflow  mcore mss mrs mboom ll

entry     s
 outflow  lls

print     pow eff radius height
print     radiusrs volrs heightrs sep
```

INTERFACE SPECIFICATION

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Example Conversion

Fortran Standalone code - TDS

- 8400 lines of Fortran code (includes TECMDL)
- Required 32 line interface definition file
- Conversion completed in < 2 hrs.
- Same model now runs standalone (called from main) or in gps environment
- Both open (once through) and closed systems have been run in gps
- Have successfully run problems with 250,000 nonlinear constraints in nested loops

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