Subsea Processing System Integration Engineering

07121-1901

TAC Quarterly Meeting

Project Team

GE Global Research

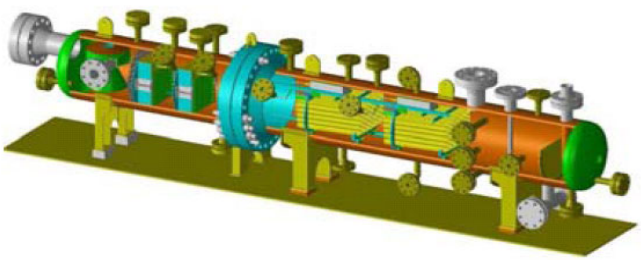
- Complex system modeling
- Statistical analysis
- Computational experimentation
- Computational Fluid Dynamics
- Sensors and Diagnostics
- Multiphase boosting

GE VetcoGray

- Over a century of experience in oil & gas
- Trees, control modules, manifolds and connection systems
- Subsea power and processing solutions

RPSEA 18-Month, $1.5M Program

Program Objective: *Build and validate a subsea processing system simulator*



Technical Approach

- Develop integrated process simulator
- Laboratory test and mobilization
- Execute the lab-scale test matrix
- Technology transfer

Technical Challenges

- Complex multivariate system
- Challenging multiphase physics
- Framework fully adaptable to future extension
- Error/uncertainty propagation

Program Deliverables

- Integrated SSP Simulator and documentation
- Laboratory tests and mobilization
- Lab-scale test matrix execution

Anticipated Benefits of the Proposed Technology

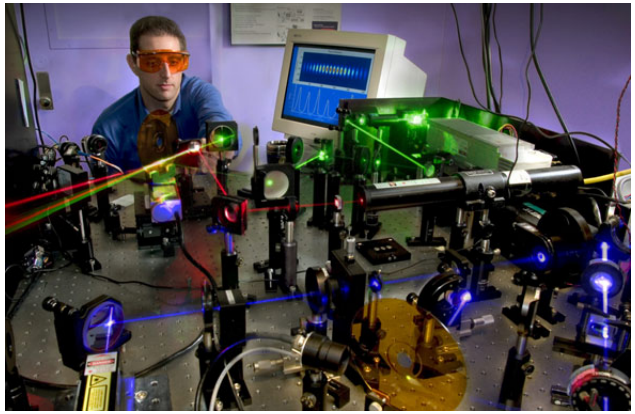
- Increased speed of SSP system deployment
- High confidence SSP performance prediction before building/deploying system
- Improved SSP component performance through use of simulator as a design tool

imagination at work

RPSEA

Research Partnership to Secure Energy for America

GE Global Research Center Niskayuna, NY



GE's world R&D headquarters

550-acre campus

1,800 technologists, majority hold PhDs

Nearly 100 research lab teams

Bangalore

Shanghai

Munich

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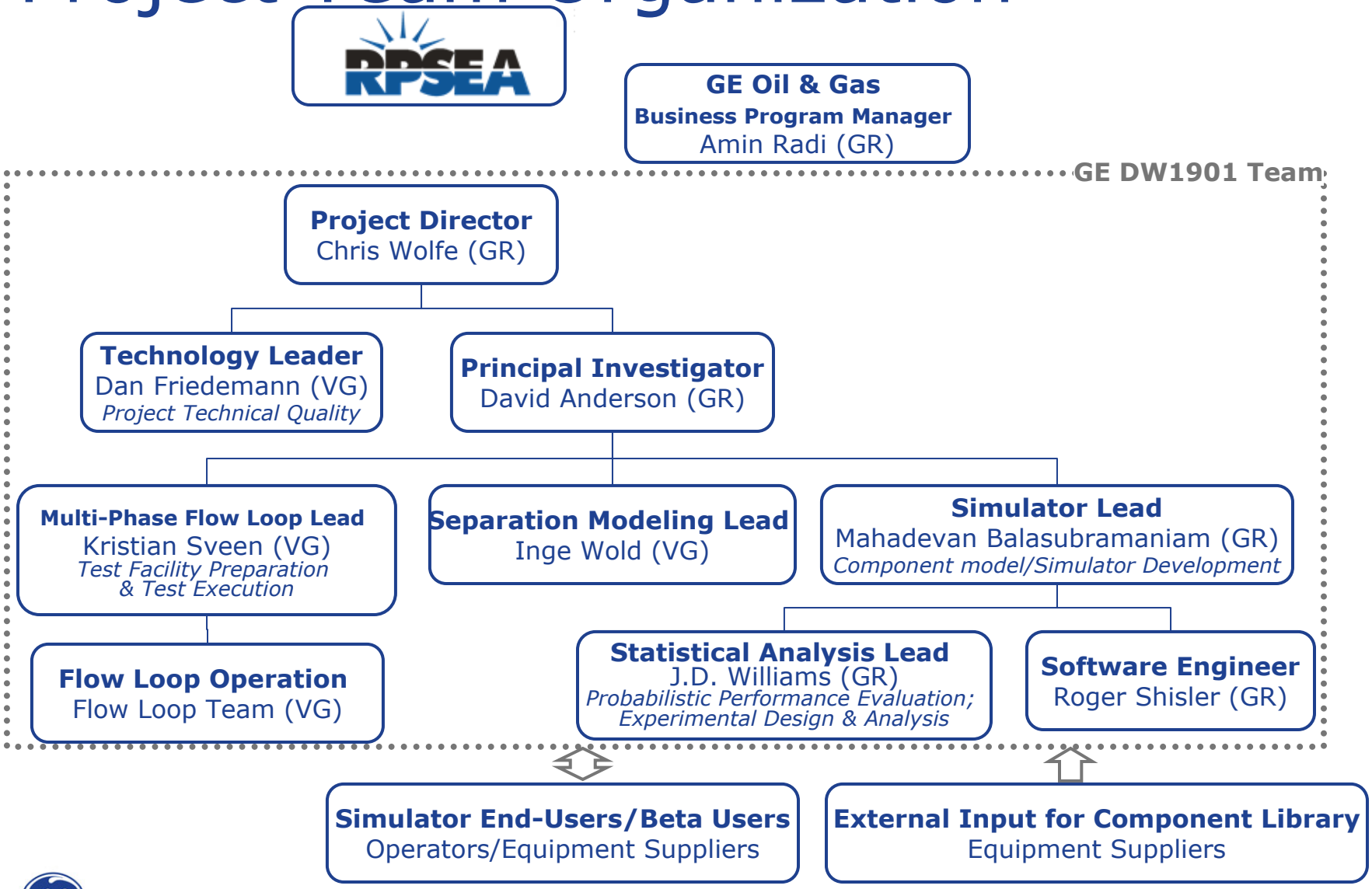
Project Team Organization



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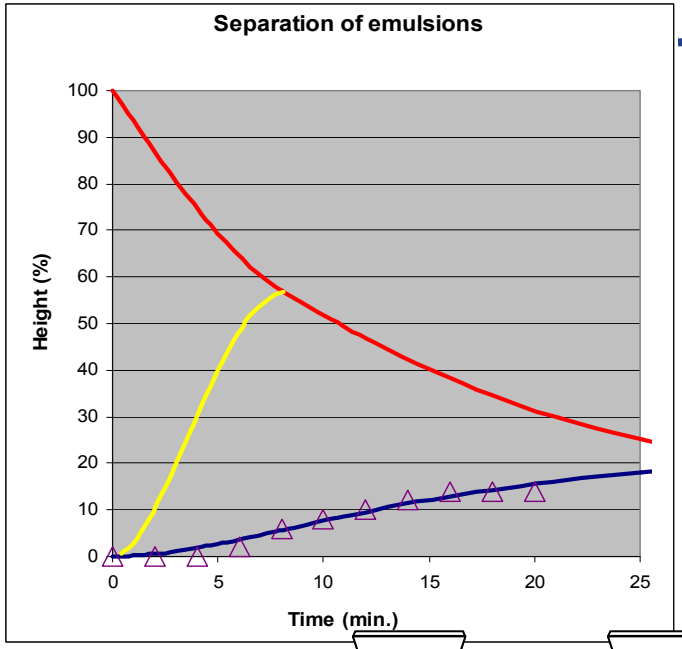
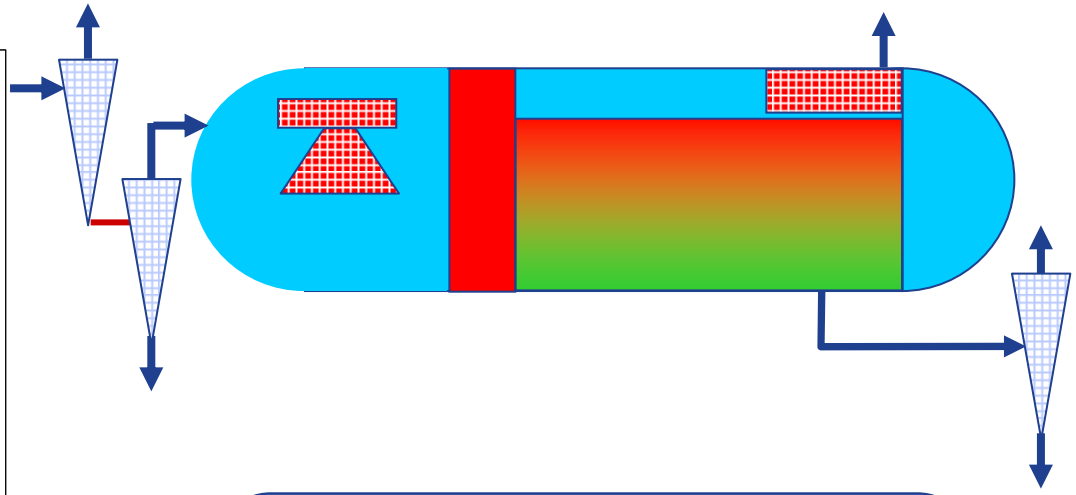
Compact Separation Challenges

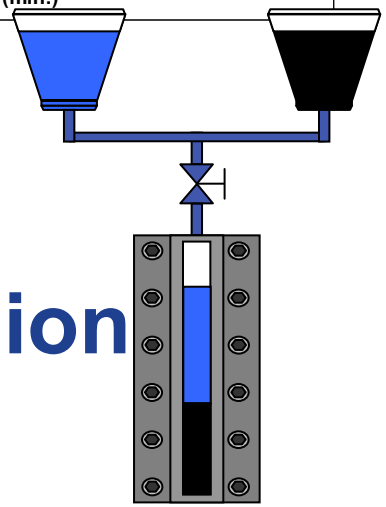




Green = Vendor Models
Light blue = CFD

Red = Major missing models:
Cross-hatched: turndown issues

Filling the gaps by flow loop testing



Lab Data Conversion

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RPSEA 1901: Paraphrase from RFP

Basic Issue: Suppliers and Customers disagree about TRL for compact subsea processing.

- Lack of good analytical process models
- Dependence on field relevant testing
- Relevance of laboratory data.
- Ability to extrapolate to new conditions

Need to develop physics-based analytical process models

RPSEA 1901: Activities

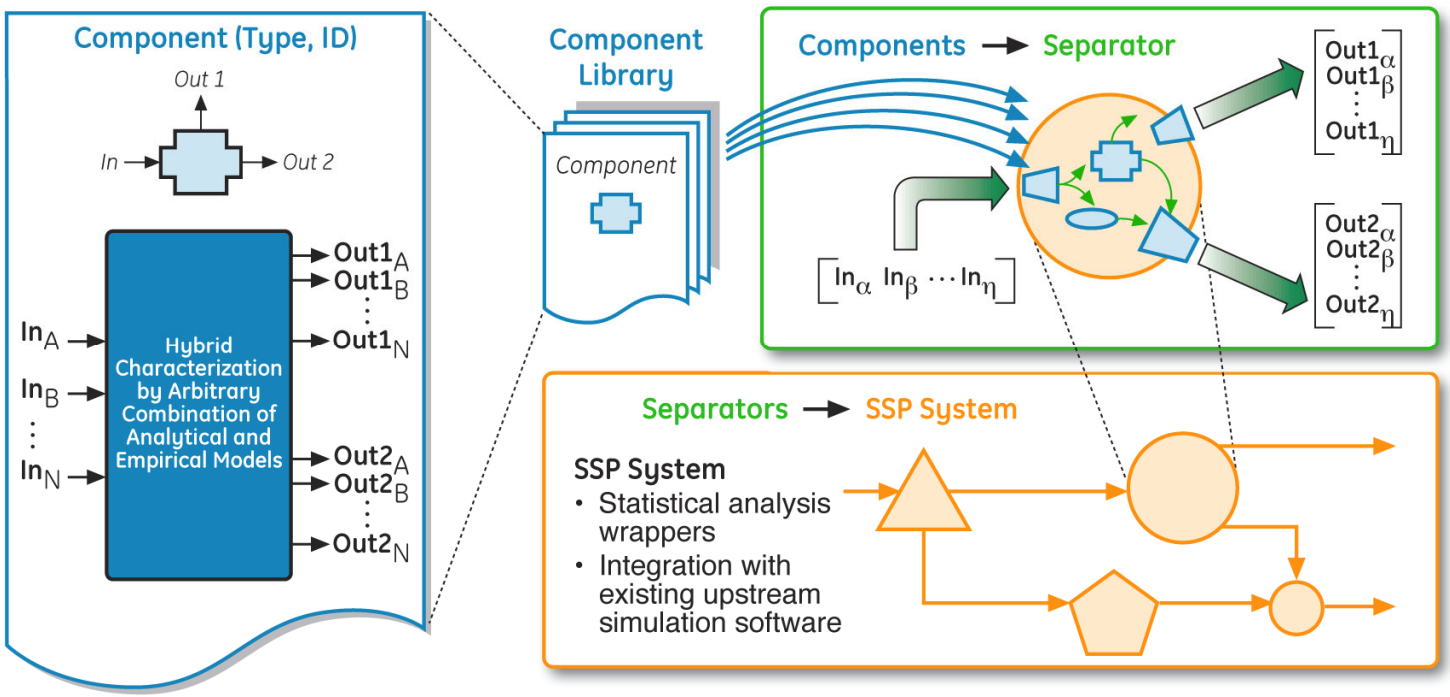
Develop:

- Robust physical and chemical models capable of accurately characterizing the expected flow regimes. **(Standard Interfaces for user models)**
- Dynamic models of each element in a compact process
  - Devices
  - multiphase piping/fittings
  - separator inlet/outlets
  - control valves
  - other associated equipment.
- Integrated Dynamic Simulator
- Test methodologies and procedures to:
  - Determine the operational envelope of each device and its system
  - Predict performance based on given field conditions and requirements.
- A facility to perform a matrix of lab scale tests to verify:
  - operating envelopes,
  - transient stability
  - control logic

Verified Design Models for Subsea Separation

Current Status

Architecture Development & Implementation



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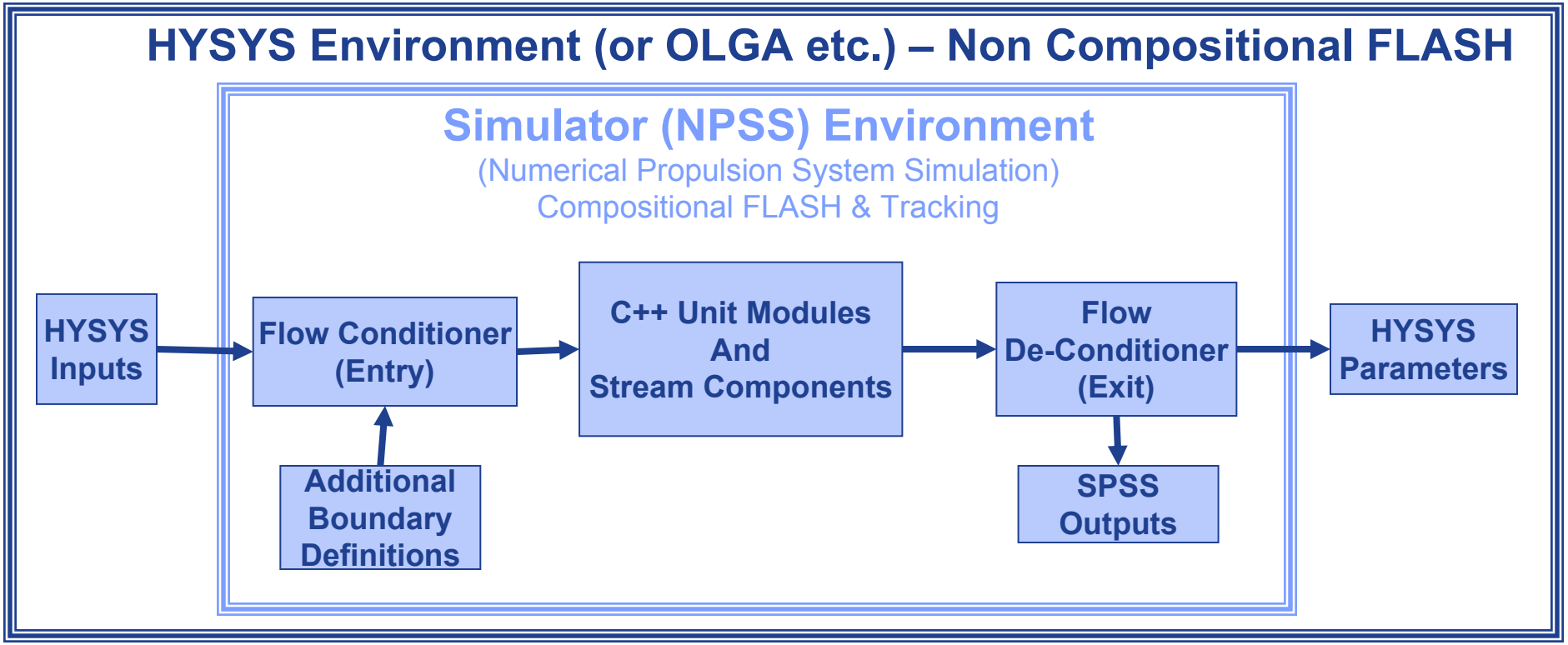
Integration with Process Simulator



Flow Conditioners allow augmentation of SPSS Simulator boundary definition where not supported by HYSYS or other production simulator.

Examples: fluid electrical properties (conductivity, capacitance), TAN, solids properties, asphaltene, wax (might be included from a separate OLGA wax table file), resins contents, scale/inorganic solids and salts, etc.

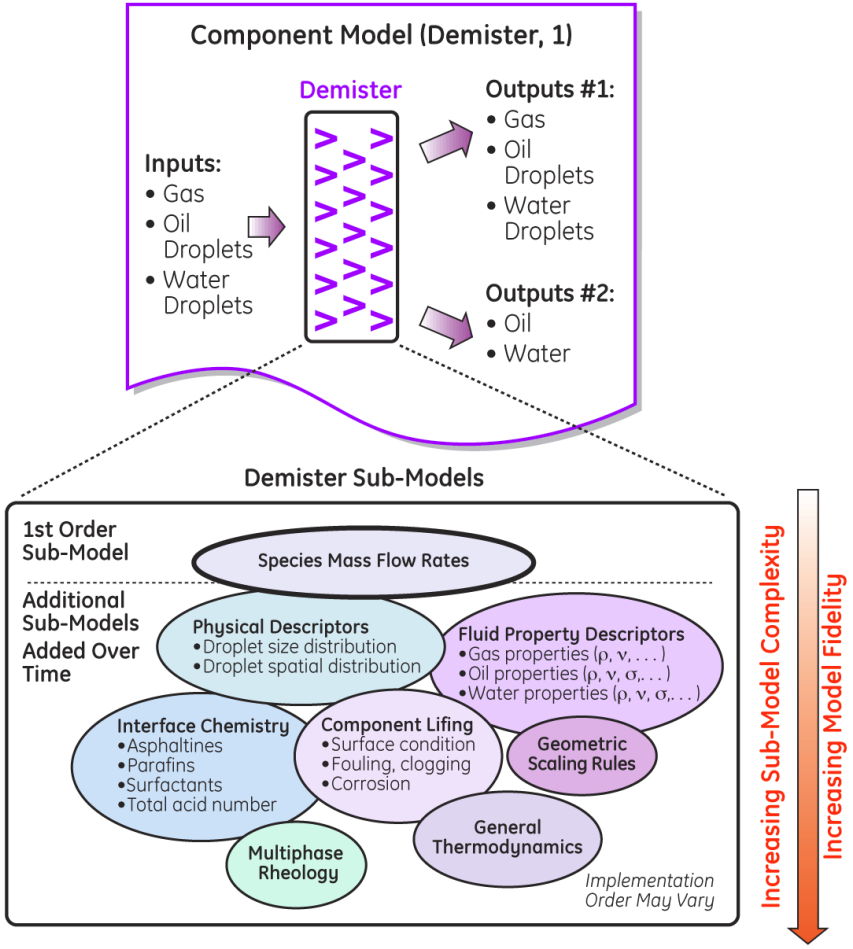
They also allow exercise of Simulator in Isolation Mode (without process simulator).

Simulator Library

The Simulator describes how the fluid streams behave as they pass through the virtual separation system using models of the following types:

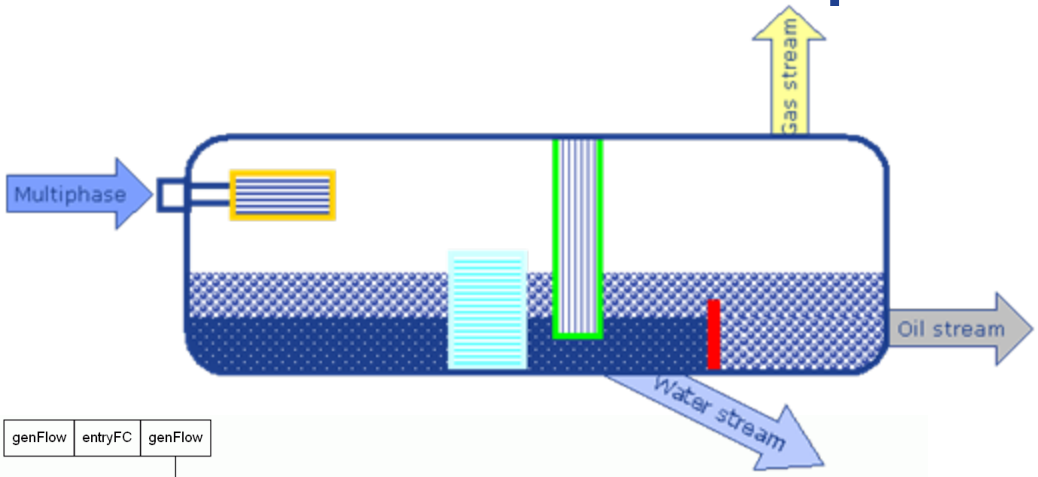
- **Unit Models** describe the effects of demisters, coalescers, pipes, flow splitters, gravity / cyclonic separation spaces, valves, and the like.
- **Process Models** include sensors, valves, and other controls. While these will likely be simple models typical of what is available in OLGA or the like, there is nothing that makes it architecturally impossible to capture extreme dynamic responses (rotating equipment, SIL rating, etc).
- **Rheological Behavior Models** include fluid property related phenomena such as emulsions.

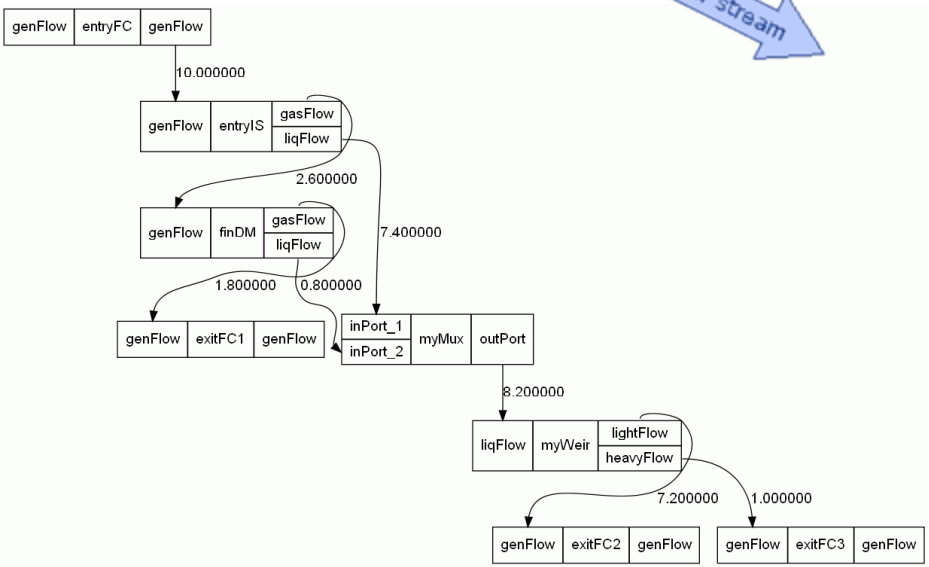
Nomenclature issue, not Simulator Architecture issue



Library is complete such that stream information accurately modified / maintained inside Simulator Environment

Three Phase Separator (Illustration)





Prototype Simulator
C++ / NPSS

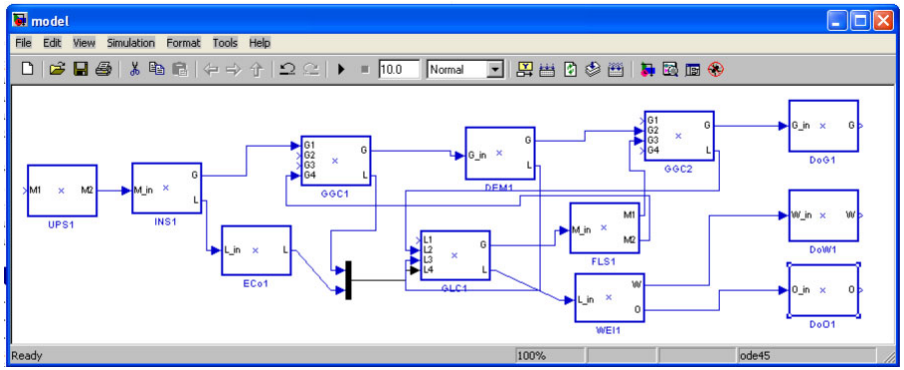
Uniquely Addressed Units

Inlet Ports

Model: Widget
Flash
Physics
Cleanup

Exit Ports

Standardized Interfaces



Sandbox Version: MATLAB

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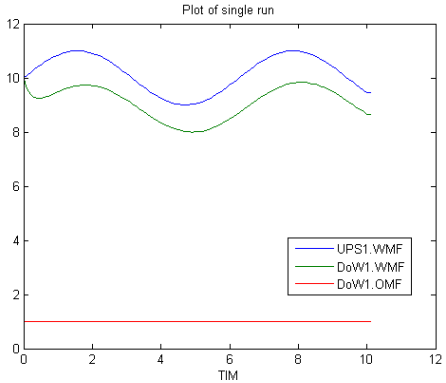
Simulator Development Strategy

Bottom up: Simple platform "sandbox" in MATLAB

- Internal development use only
- Start with ad hoc models: Determine architecture of unit models, stream definitions, data structures, solver design, etc.
- Add increasing capability & complexity. Ensure that architecture has legs to achieve program objectives.

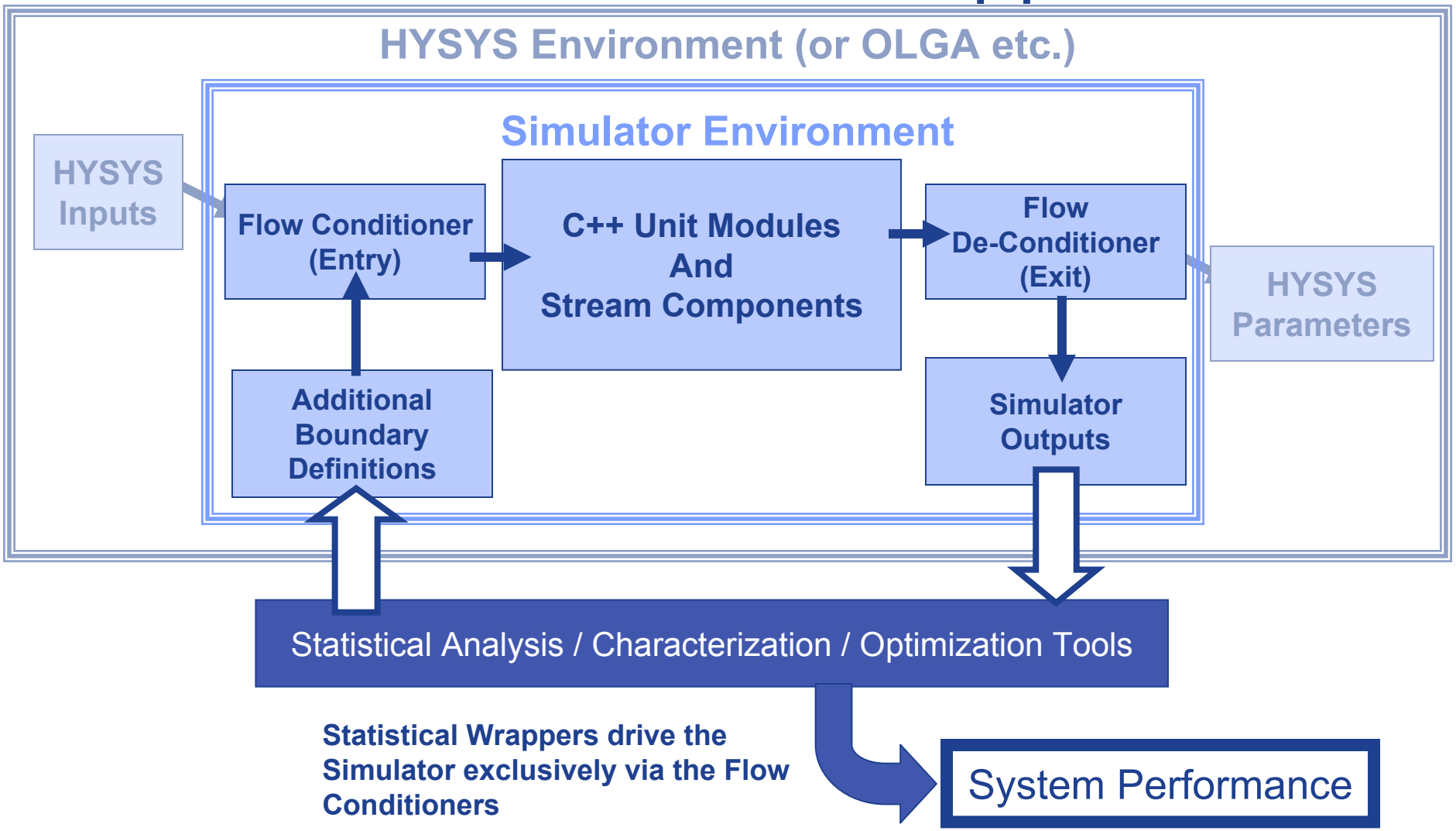


Top Down: Numerical Propulsion System Simulation (NPSS) Tool / C++

- Development of full-on Simulator framework.
- Establish data structures, system assembly, stream definitions, helper functions, hooks to HYSYS, etc.
- Populate libraries of models, create utilities, etc.

Execution on Two Fronts for Risk Minimization

Simulator Statistical Wrappers

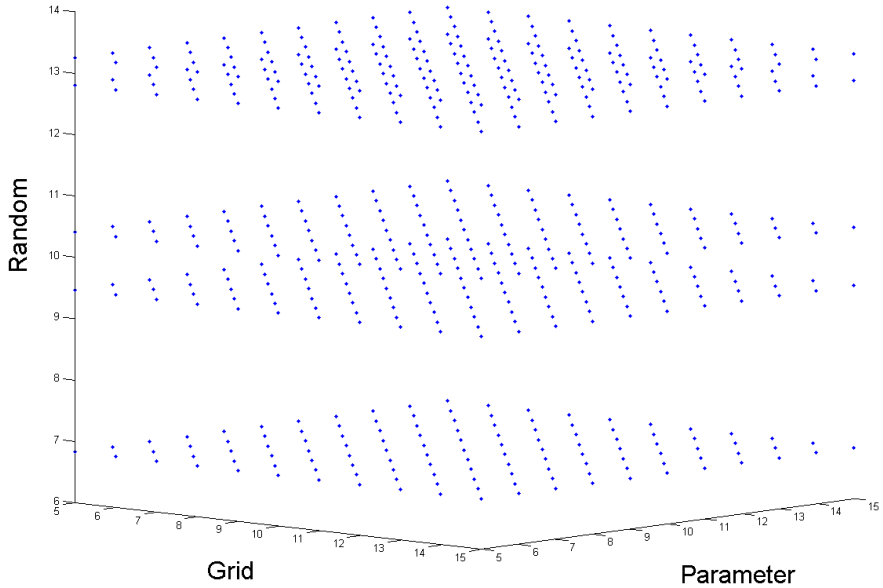


Pre-processor

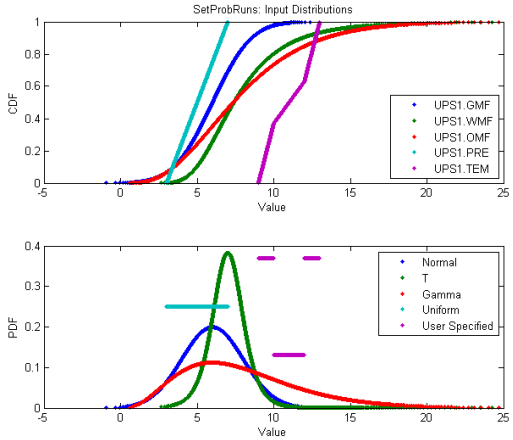
Generate the set of simulation cases:
---Stream, Global, & Parameter values

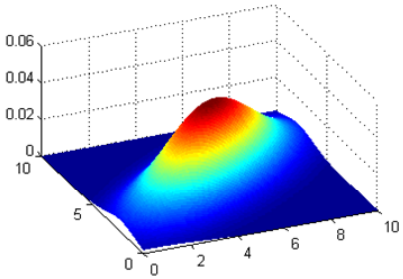
Any combination of:

- Randomly distributed inputs
  - Chosen according to likelihood of occurring
- Gridded inputs
  - Chosen to determine operational boundaries
- Design parameters
  - Chosen for stochastic/probabilistic design



Steady state
or transient





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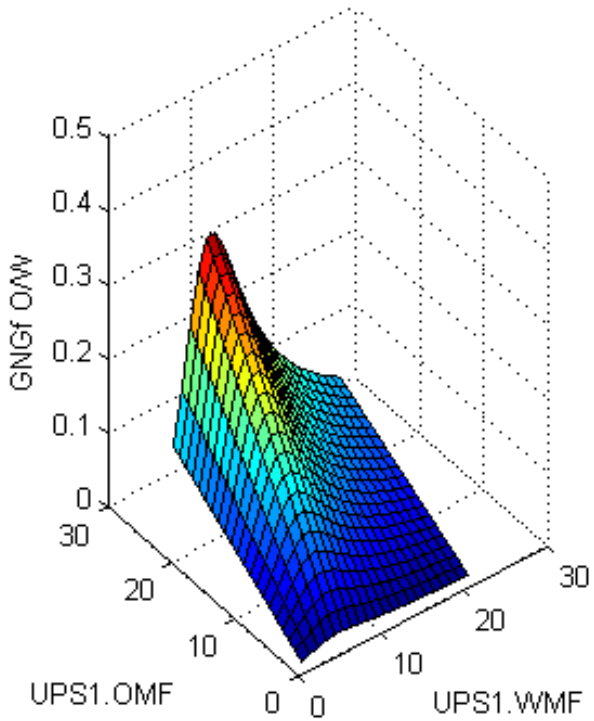
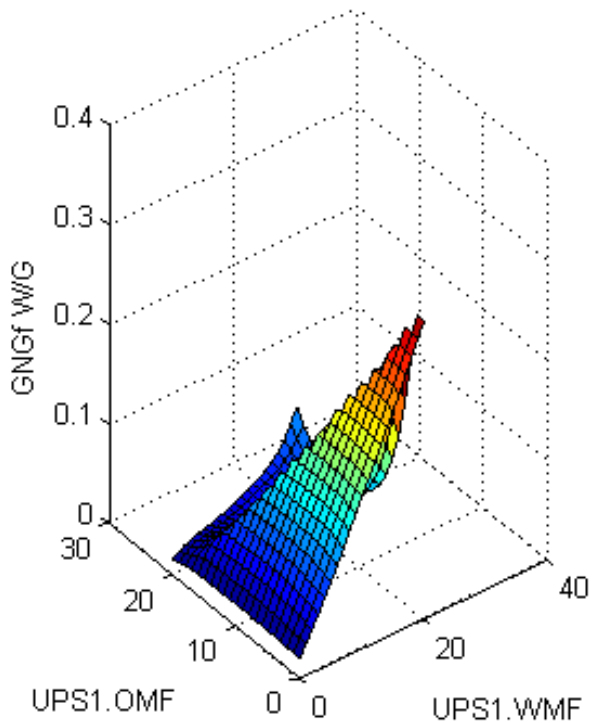
Operational Envelope: Multiple Criteria

1. Overall system performance
2. Unit performance
3. Model applicability

#1: f_1(Outputs)



#2 f_2(Outputs)



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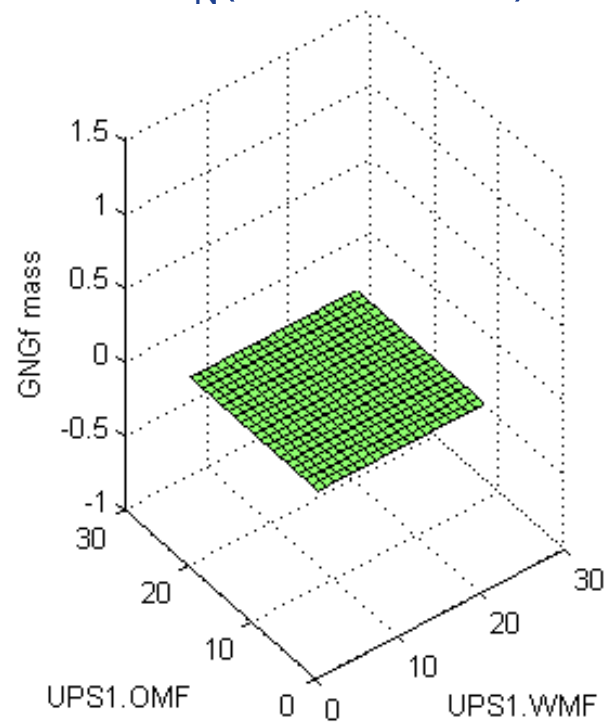
#N: f_N(Parameters)



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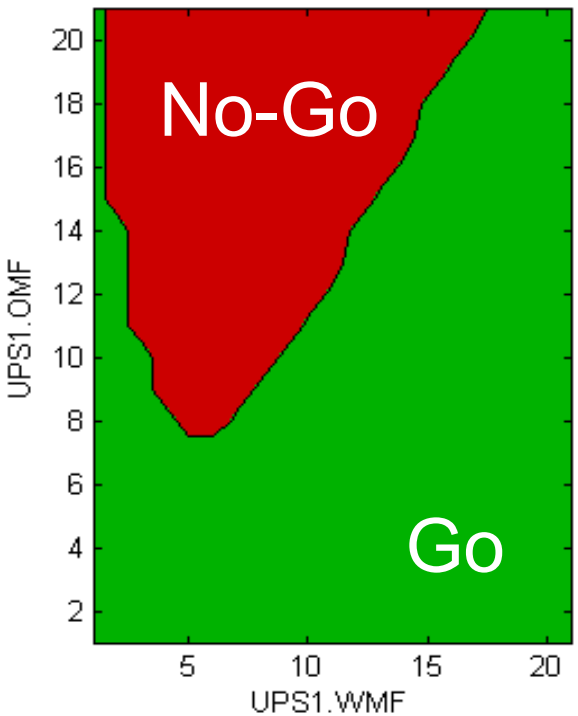
Operational Envelope:
Combining Several Evaluation Functions

Combine multiple go/no go maps to determine overall system envelope

Output I



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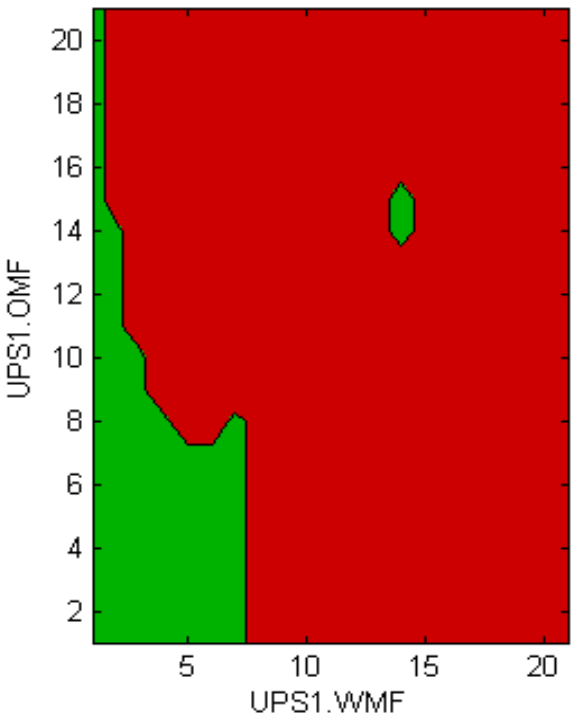
Output J

Intersection(I…J)



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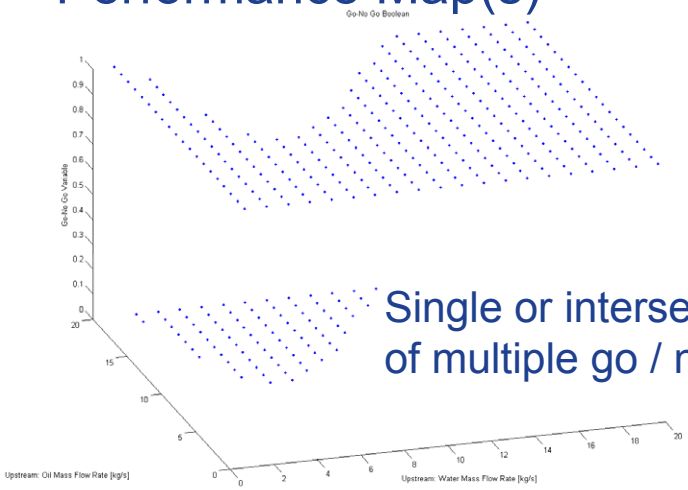
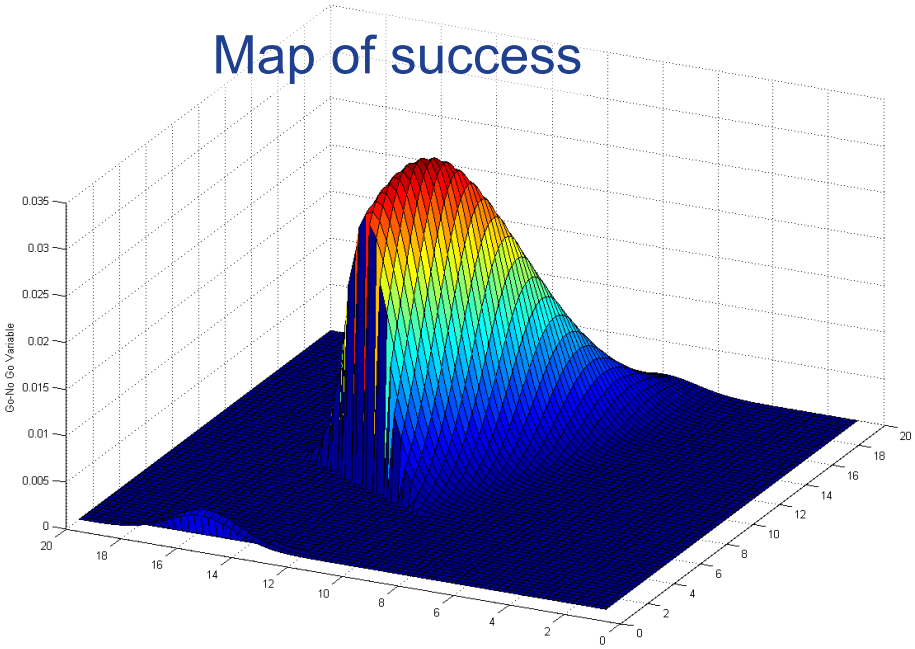
Performance Statistics

Performance Map(s)

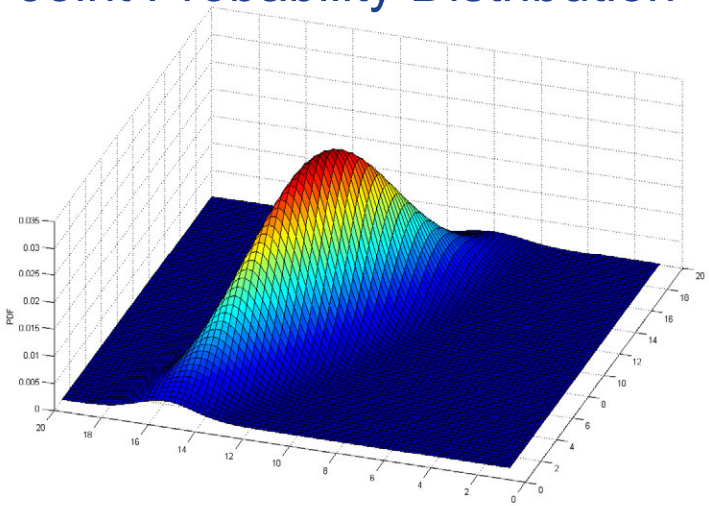


Single or intersection of multiple go / no-gos

Map of success



Joint Probability Distribution



Volume under this curve is the probability of success of the design system

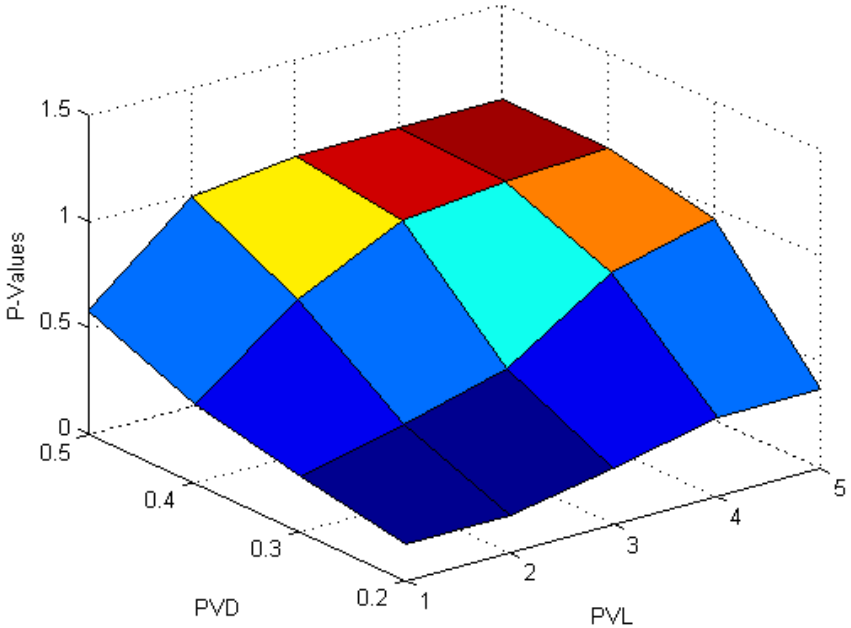
NOTE: A performance metric map can also be multiplied by the probability map. Volume Integral is then a measure of total expected value

Performance Statistics

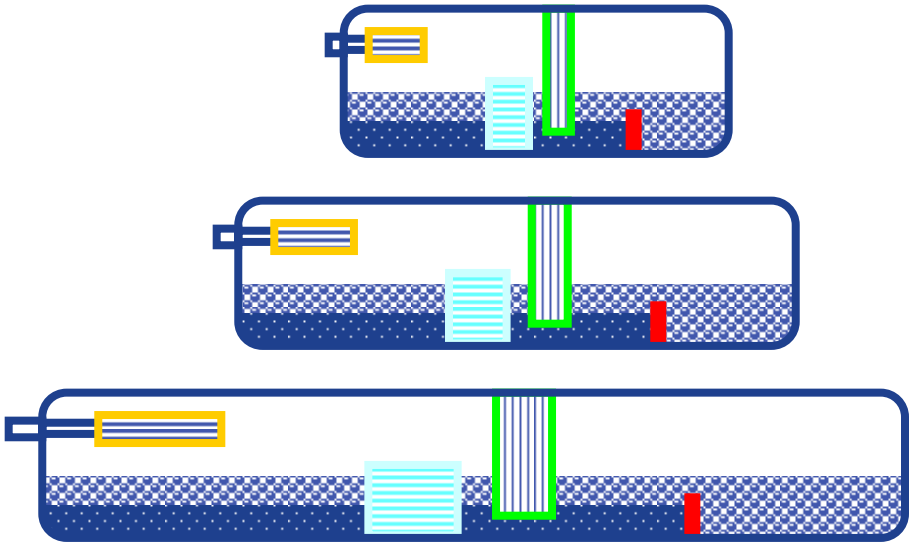
After calculating success for each parameter set:

Plot probability of success as a function of the design parameters.

Can do this with any/all combination of go no-go functions.

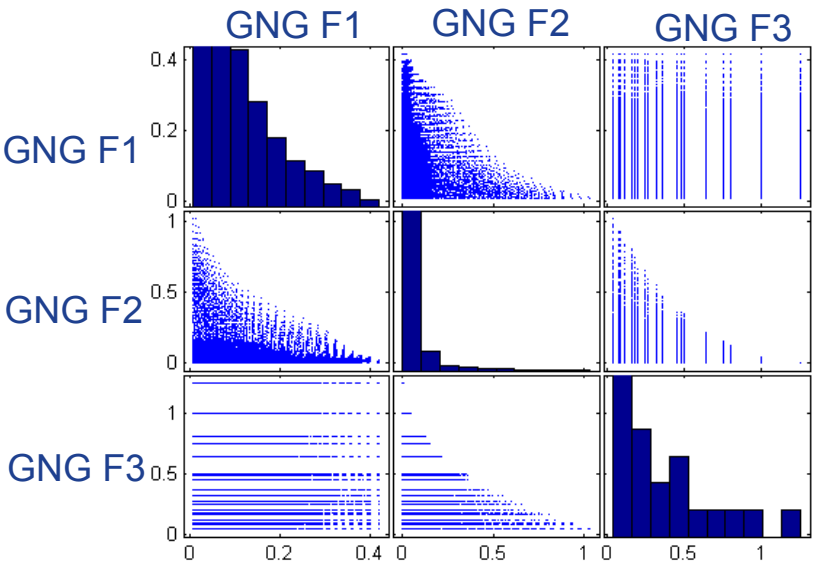


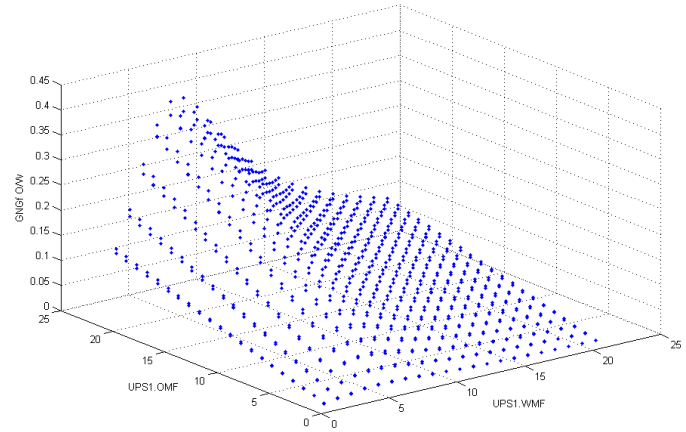
Probability of success vs. Parameters

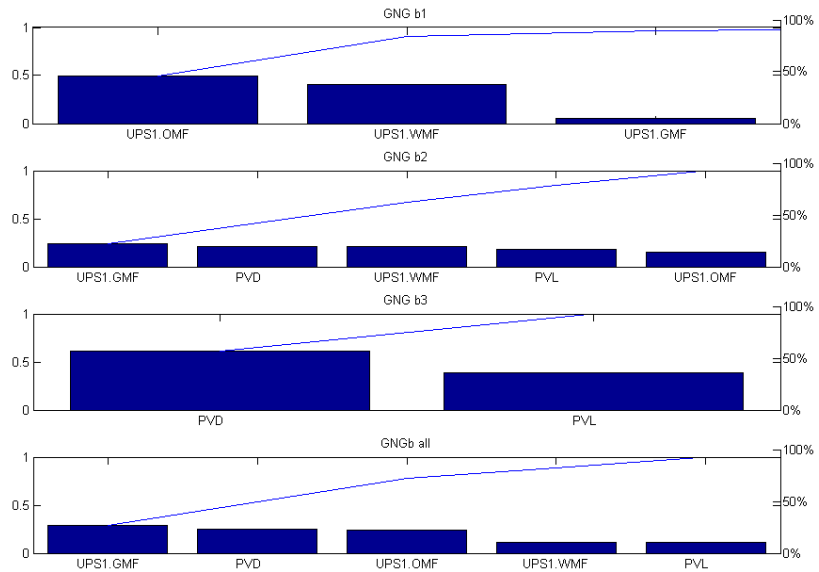


Example: Varying vessel size

Significant Variables & Correlations







Determine key relationships

- Performance & inputs
- Performance & design
- Cause and effect

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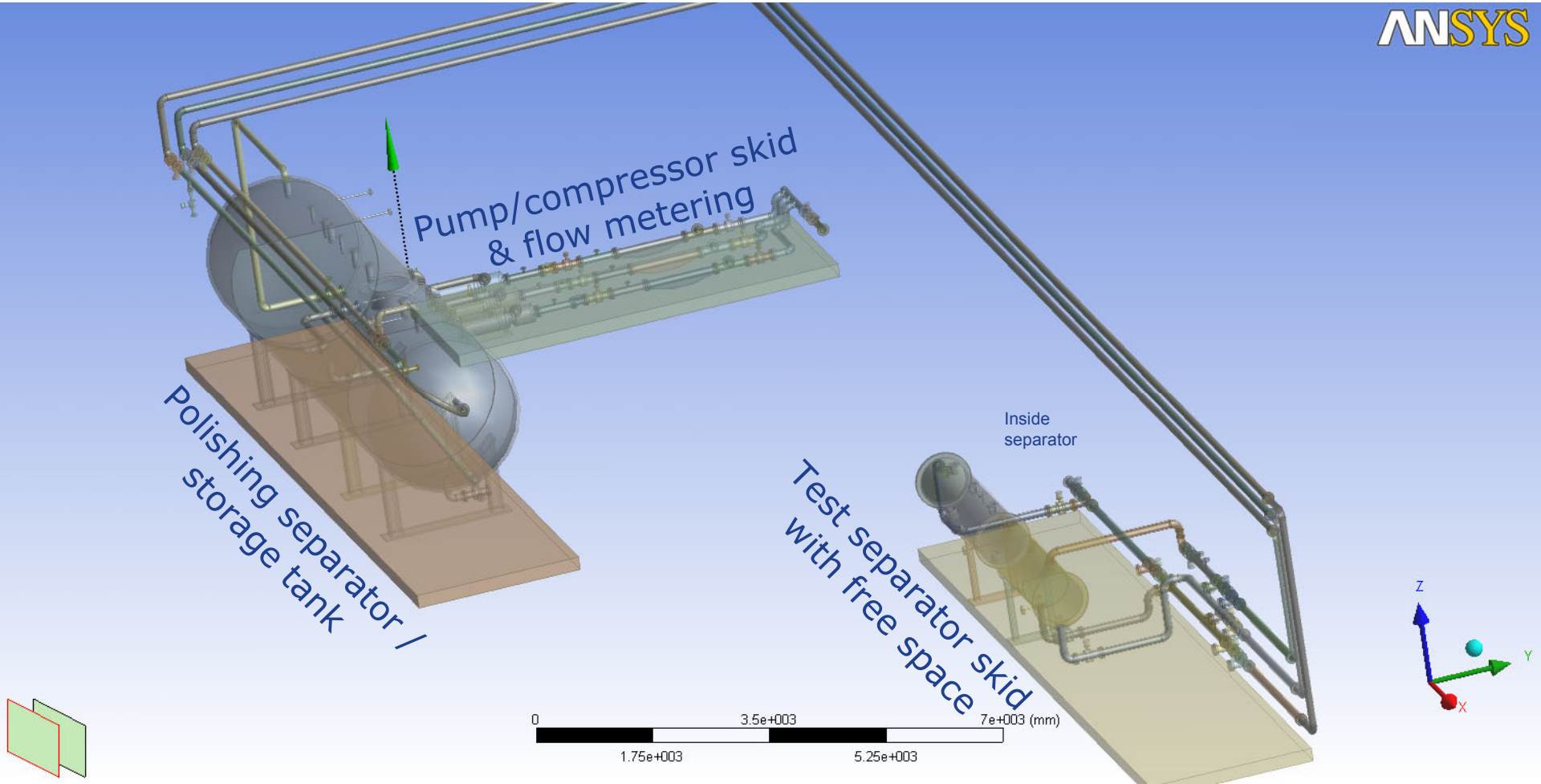
Experimental Facility

4” piping
40 bar max operating pressure
5000m^3/day (208m^3/hr)
4 to 70° C

RPSEA Requirements
- Test Section to be skid mounted
- Test Section to be crude oil compatible
- Model fluids
- Allow “black box” units

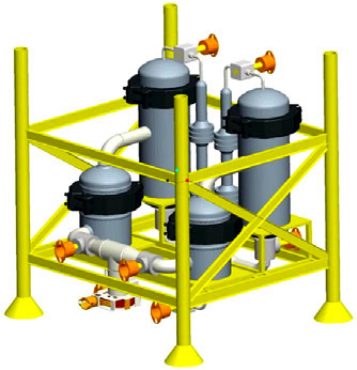
- Salt water (3-10% salts)
- Model oils, flashed crude oils (no explosive gasses)
- Synthetic crudes from the Ugelstad laboratory (FACE)
- CO2, N2, air

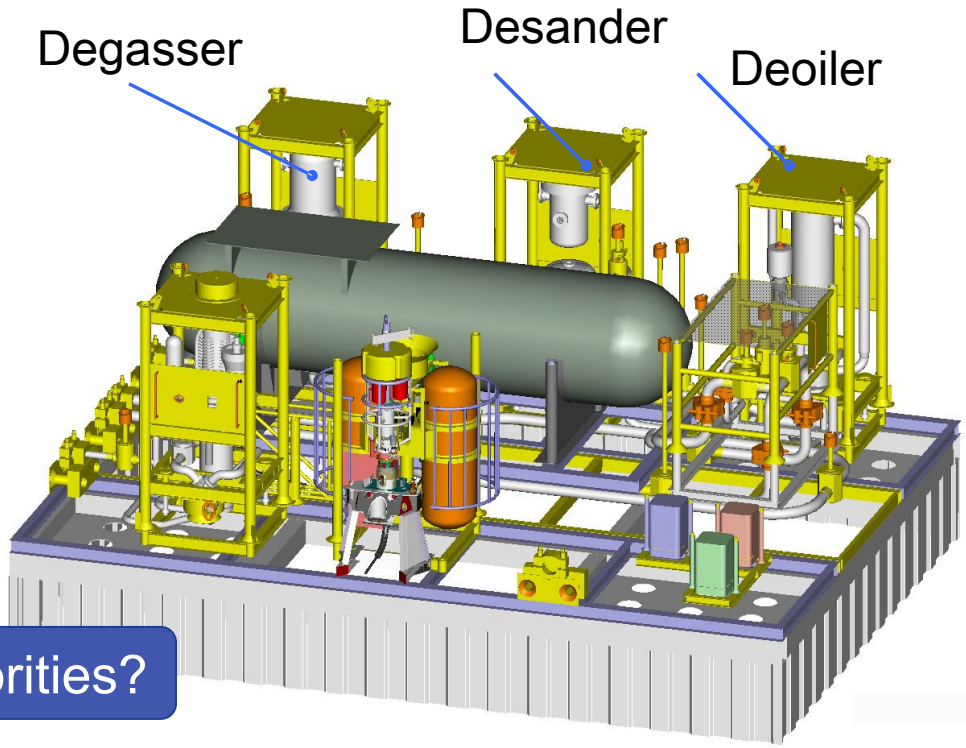


Devices to be tested

All compact subsea separation tools

- All Separator Internals
- Cyclones: degassing, dewatering, deoiling
- Inline coalescers
- Sensors and Controllers





Priorities?

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Hierarchical Simulator

Operation Engineers
Specification & Operation

Equipment Suppliers
Design & Optimization

RPSEA Phase 2
Pilot Scale

RPSEA Phase 1
Lab Scale

Simulator Architectural Entitlement

Simple Processing Systems
Simple Component Models
Simple Component Interfaces
Simple Fluid Systems & Chemistry
Low Fidelity
Low Resolution
Computationally Inexpensive
Easy to build & troubleshoot

Increasing Complexity

Zooming

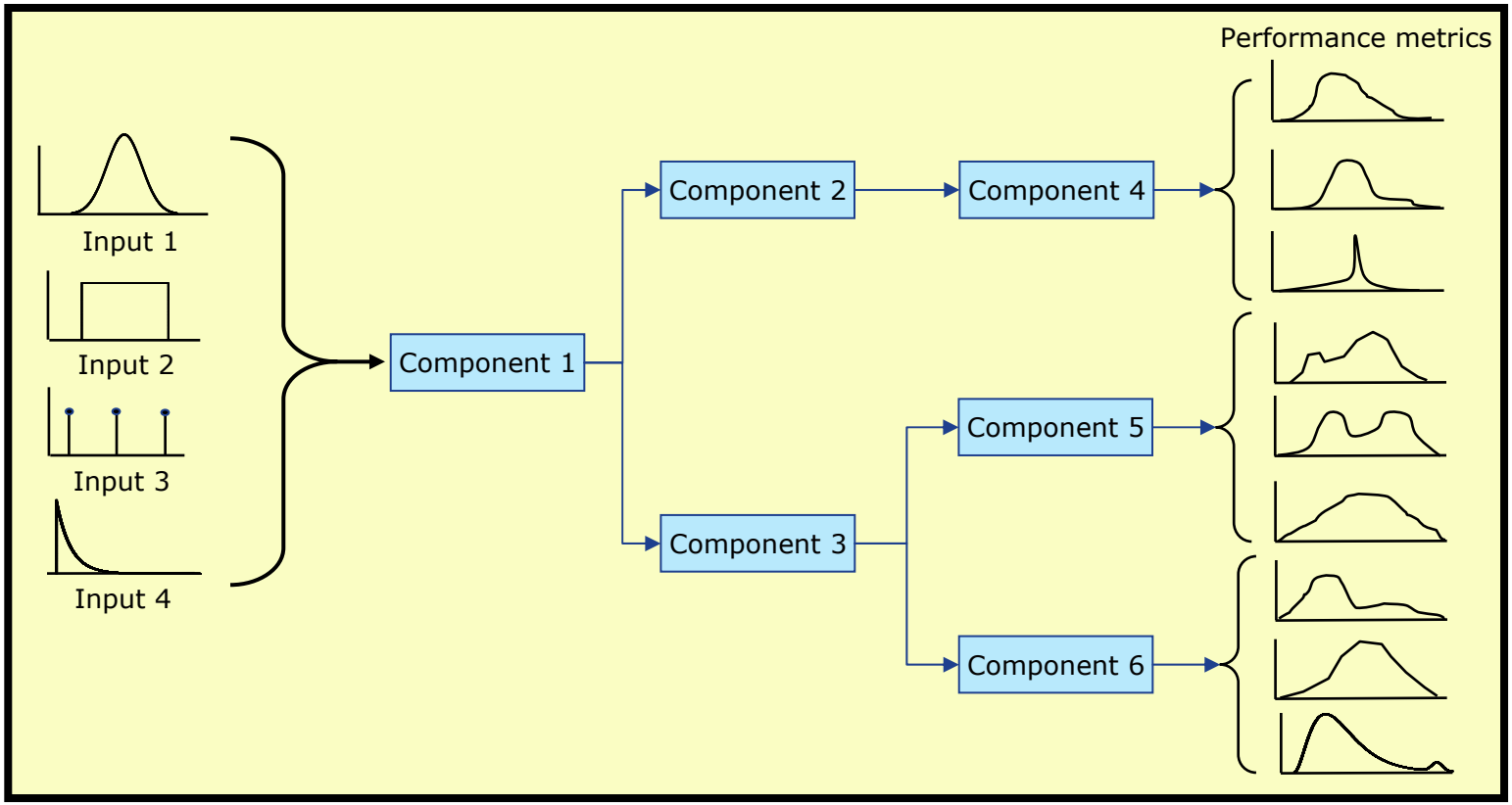
Complex Processing Systems
Complex Component Models
Complex Component Interfaces
Complex Fluid Systems & Chemistry
High Fidelity
High Resolution
Computationally Expensive
Evolved from simpler models

- Operation
  - Mass Balance/Thermodynamics → Transfer Fn → CFD
- Stream
  - Basic Oils → Droplet Model → Interface Chemistry

Seamless transition from Simple → Complex Models

SSPS Performance Evaluation

EXAMPLE



HYSYS upstream

HYSYS downstream

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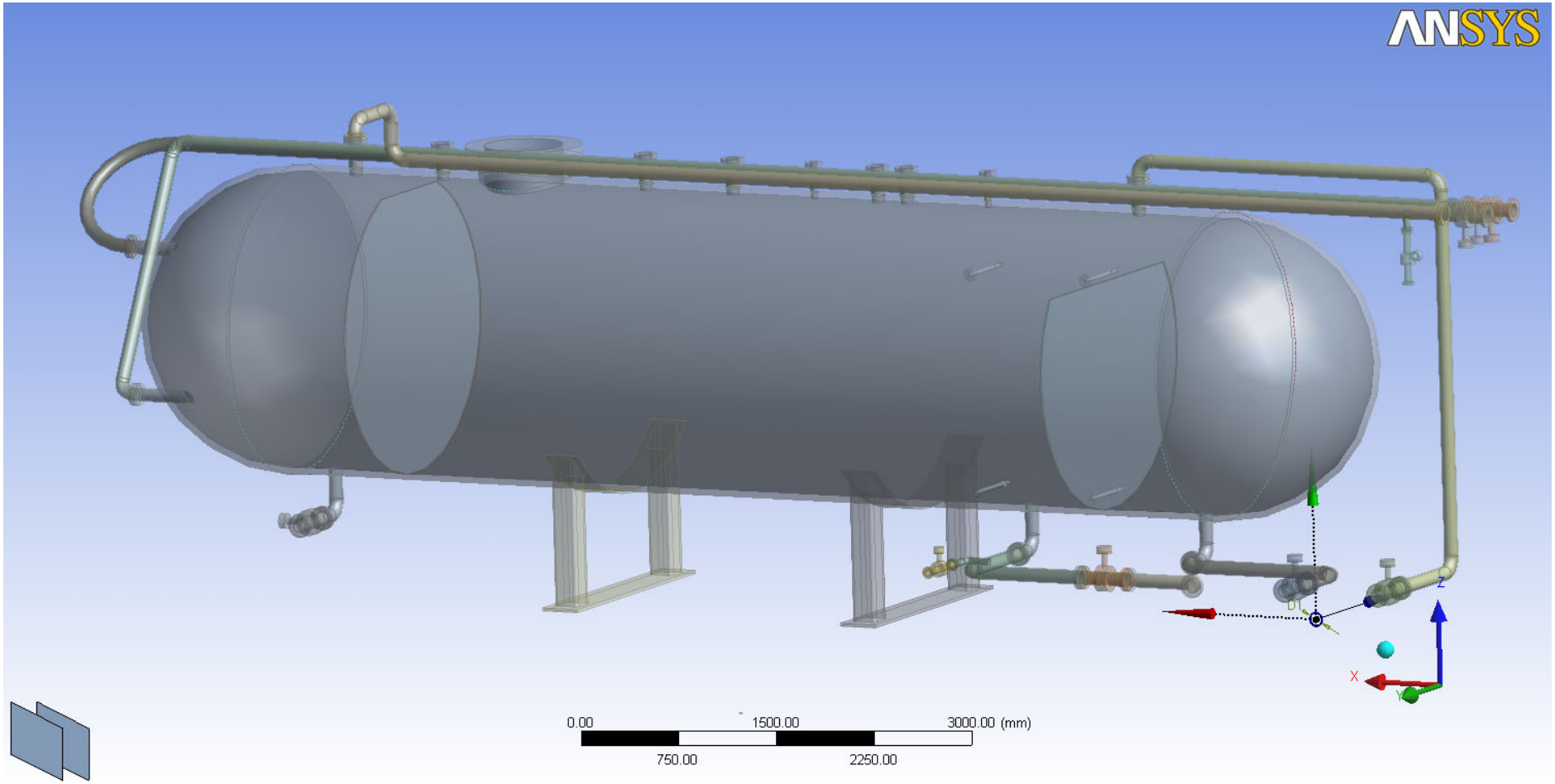
Polishing/storage skid (2.55m x 12m)

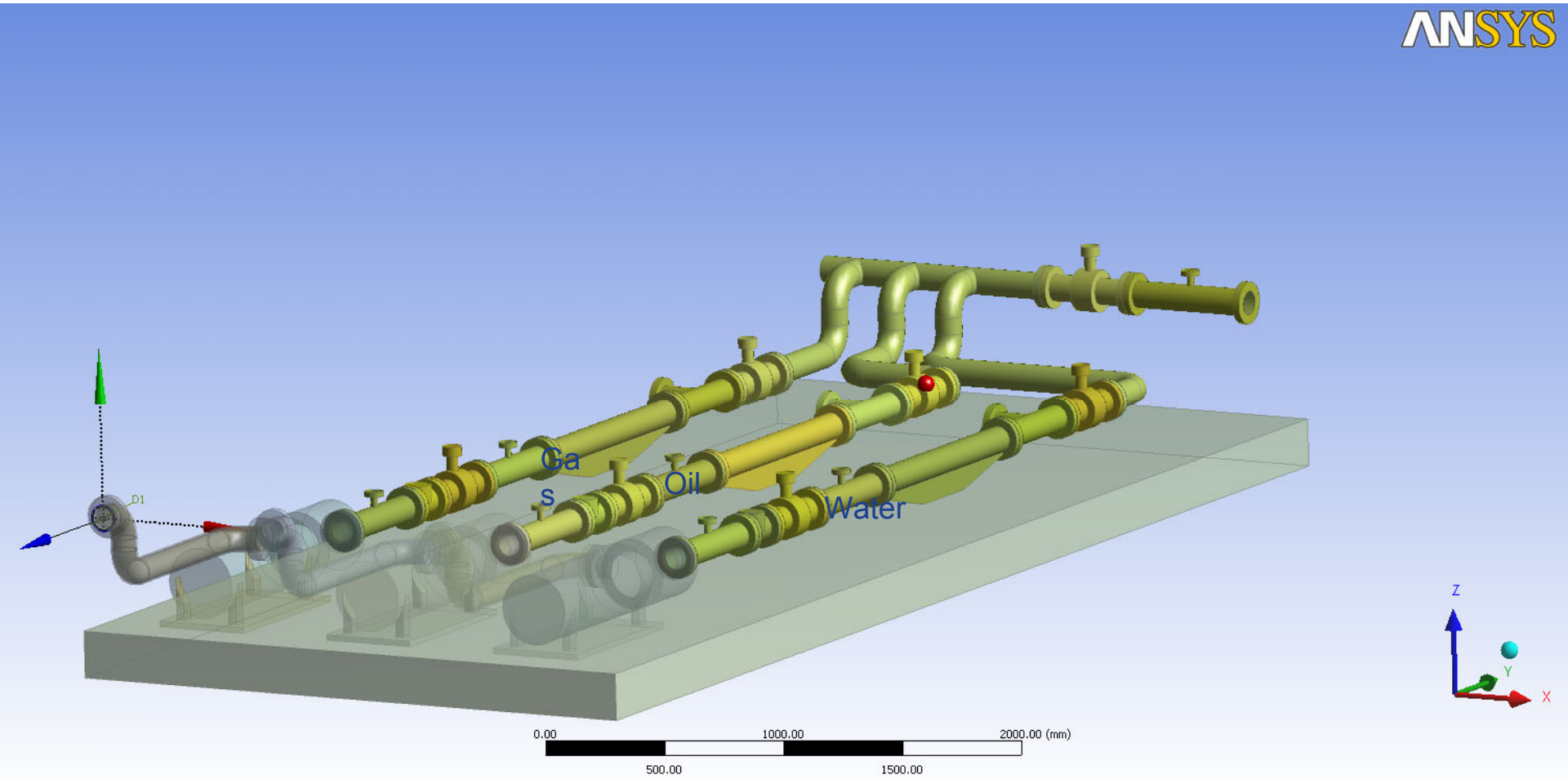
- 2.3m ID
- Seam2Seam 8m
- 39.72 m^3
- 24” manhole
- 4 of 1” flanges for level gauges
- 14 of 4” flanges
- 2 of 2” flanges
- Mounting brackets@regular intervals
- 1 single perforated plate
- System pressure set through Gas Phase via pressurised O2 or N2



Pumping Skid (2.55m x 6m)

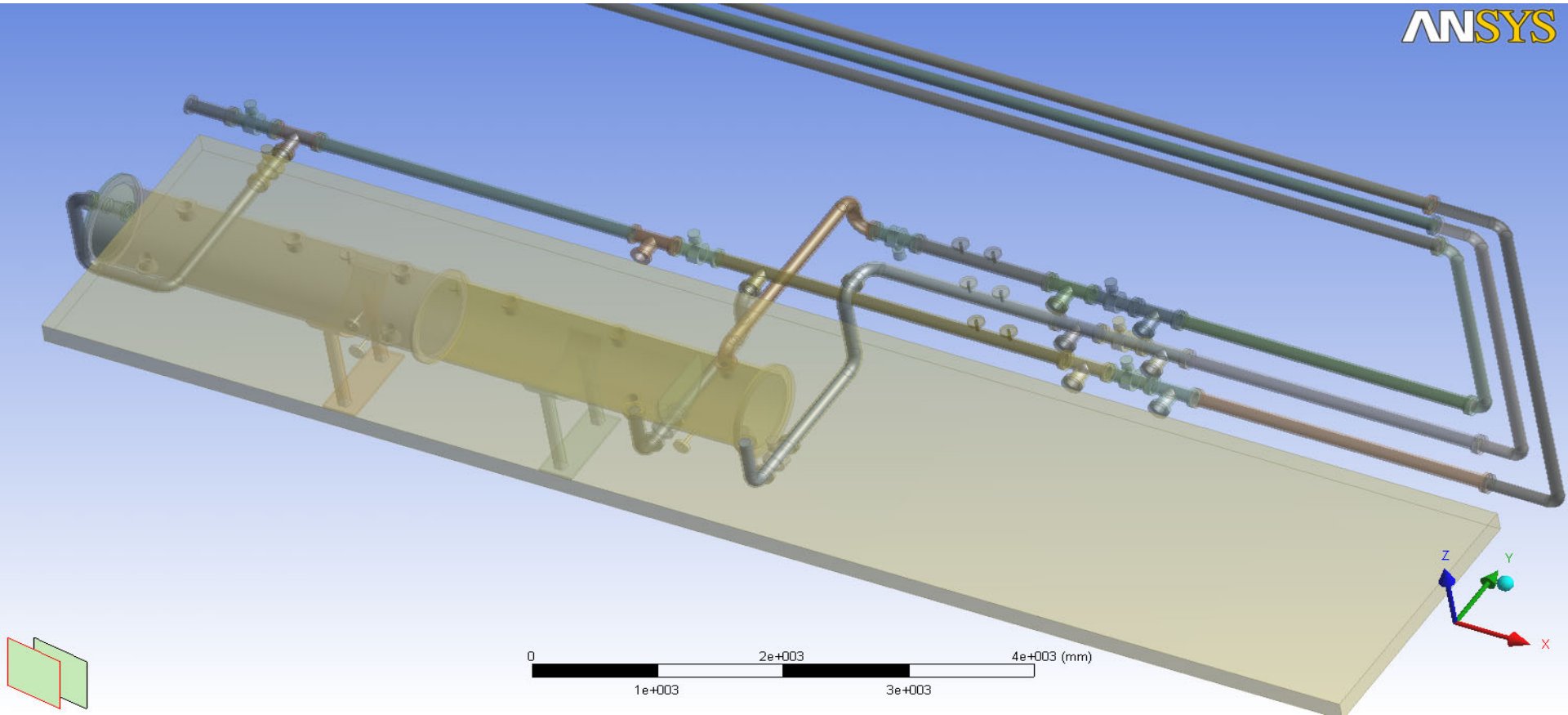
Drawing shows ”generic” pumps w approximate dimensions

Pumps/compressor: 0-~20 bar lift, 208m3/hr – turndown may be an issue



Test separator skid (2.55m x 12m)

- 2*3m long (5.3m S2S),
- 0.7m ID separator(s)
- 10 of 4” flanges
- 2 of 2” flanges
- 4 of 1” flanges for level gauges

- Body flanged – possible to simulate
  - 1x6m separator or
  - 2x3m separators in parallel or serial setup

> Equipment testing
  - Inside separator
  - Passthrough line or O/W/G lines individually