Remote Access Networked Models in a Collaborative Power Industry Application

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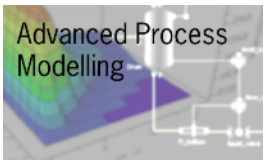
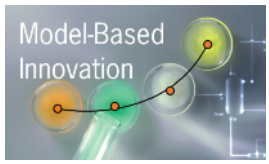
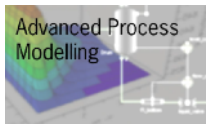


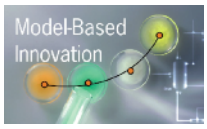


Overview

- The VPDM project
- Inter-organisational collaborative modelling
  - accessing CAPE-OPEN Units across the internet/intranet
- Wrapping legacy units for CAPE-OPEN
- Conclusions

Virtual Plant Demonstration Model (VPDM)





Virtual Plant Demonstration Model

- 3-year R & D project
  - to 30 June 2007
  - focus on power industry
  - partially funded by
    UK Department of Trade and Industry under its
    Carbon Abatement Technologies Programme
- Project focus:

"Arm's-length"
inter-organisational
collaborative modelling

ALSTOM

ME Engineering Limited
sustainable energy solutions

MitsuiBabcock

RWE

Engineous

ANSYS FLUENT

PSE

UNIVERSITY of ULSTER

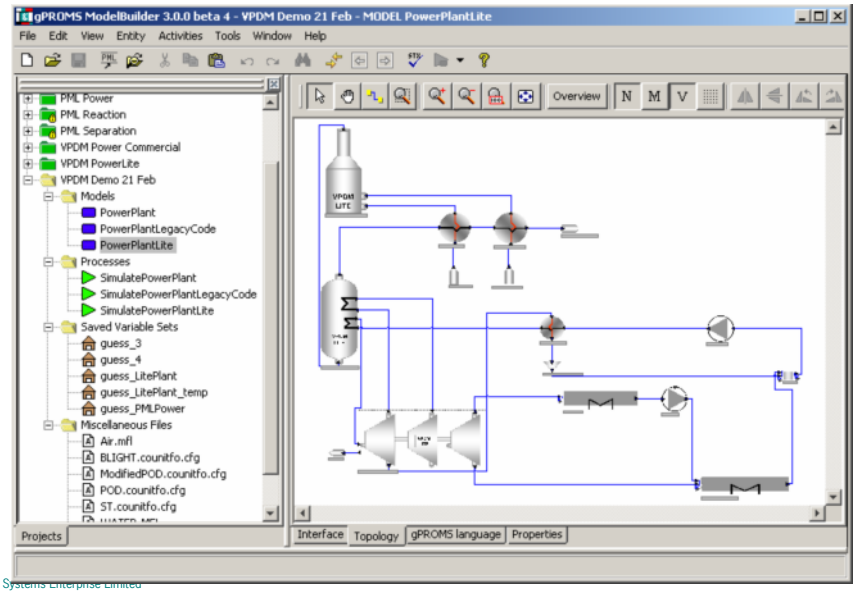
"Arm's-length" inter-organisational collaborative modelling

- Equipment vendors provide restricted access to models of their equipment to plant designers or operators
  - …with whom they may actually be competitors in other projects/contexts
- Unit operation models are <u>always</u> located with their owners
  - …accessed remotely under strictly controlled technical/legal conditions
  - safeguards against "reverse engineering"
- Need to ensure secure interoperability across internet, company firewalls etc.

VPDM additional requirements

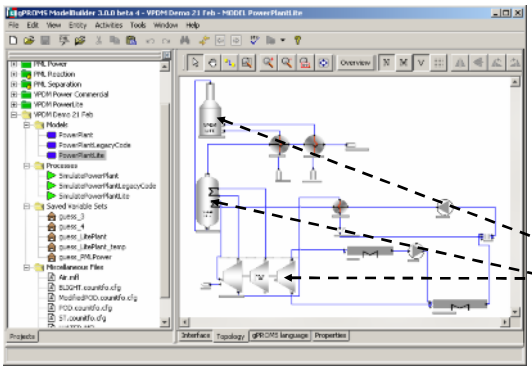
- CAPE-OPEN compliance
  - the software framework should not be tied to any specific Process Modelling Environment (PME)
  - CAPE-OPEN chosen as the interoperability protocol
    - strongly advocated by PSE….
- Re-use existing legacy codes as unit operations
  - no knowledge of COM or CAPE-OPEN should be required
  - should be possible to treat the legacy code as black-box
    - in the extreme case, the original source code may not be available
  - just write some simple i/o wrappers around existing code
    - should require no more than "standard" FORTRAN programming skills

For example…

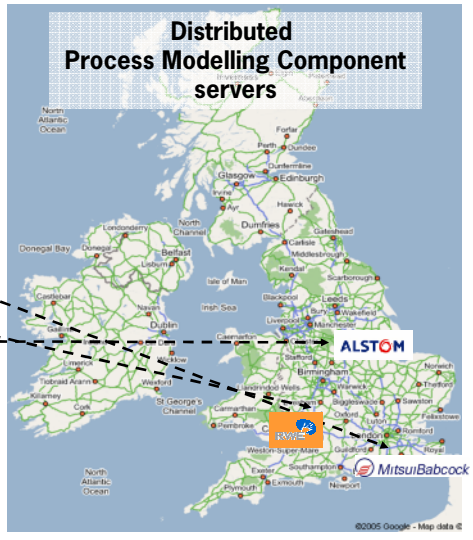


For example…

Process Modelling Environment client



Distributed Process Modelling Component servers



PSE's role in VPDM

- Design & implement overall software architecture
  - liaising with other software partners
    - Engineous : FIPER®
    - Fluent : FLUENT® CFD code & APECS
- Bring in knowledge of CAPE-OPEN
  - gO:CAPE-OPEN
  - CAPE-OPEN Thermo Foreign Object
- Support in development & testing
  - gPROMS® as the Process Modelling Environment
    - extended with CAPE-OPEN Unit Socket **(Paper #535e, 1:54pm today)**
  - process modelling expertise

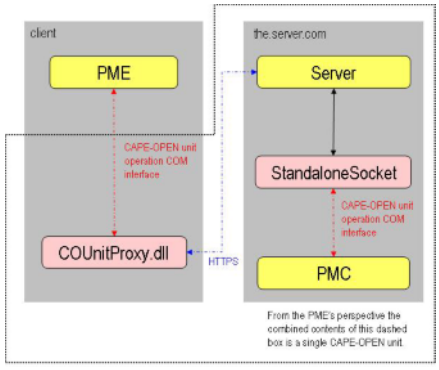
Accessing CAPE-OPEN units remotely across the internet/intranet

Remote CAPE-OPEN Units

- 'Remote CO Unit':
  - a CAPE-OPEN unit operation that is installed and executed on a computer other than the one on which the PME is executing
- Secure access over public internet
  - across company firewalls
  - acceptance/approval by company IT departments a major consideration

Architecture overview

- Use simple proxy→server architecture
  - with SSL-encoded plain text communications between them
- Requires a component to act as a simple PME on the server side
  - StandaloneSocket: a text and file-driven PME that allows a single unit operation to be plugged into it



Example
INITIALIZE request: client → server

```
INITIALIZE

PROGID
   "PSEUnitLibrary.COUnitFIPERProxy.192_168_0_172_vpdm_LegacyLightBlight.1"
```

Client requests remote PMC to initialise itself…

Example
INITIALIZE response: server → client

```
INITIALIZE_RESPONSE

PROGID        "PSEUnitLibrary.COLegacyUnit.BLIGHT.1"
# CLSID       "{F45B09AC-9009-4498-96B1-38426DBE7DD8}"
NAME          "BLIGHT"
DESCRIPTION   "Light Boiler Model provided by MBEL"

# Parameters
INPUT         "SteamDemand"
DESCRIPTION   "The steam flow required by the HP turbine"
REAL          400 : 100 : 500

OUTPUT        "FeedWaterFlow"
DESCRIPTION   "Required feedwater mass flow"
REAL          400 : 100 : 500

# Ports
INLET         "HotGasInlet"
DESCRIPTION   "Hot gas from Furnace exit"
MATERIAL

OUTLET        "GasOutlet"
DESCRIPTION   "Gas leaving boiler"
MATERIAL
```

PMC identification

Input/output (non-stream) parameters

Inlet/outlet streams

Example
CALCULATE request: client → server

```
CALCULATE

MASS

INPUT  "SteamDemand"
425.0

OUTPUT "FeedWaterFlow"

INLET       "HotGasInlet"
MATERIAL    "PSEThermoLibrary.DummyThermoSystem<7732-18-5, 7782-44-7,
             124-38-9, 7446-09-5, 7727-37-9, 7440-37-1>"
PRESSURE    100000.0
TEMPERATURE 1300.0
FLOW_V      [40.0,  20.0,  44.0,  48.0,  350.0,  2.0]
FLOW_L      [ 0.0,   0.0,   0.0,   0.0,    0.0,  0.0]

OUTLET      "GasOutlet"
MATERIAL    "PSEThermoLibrary.DummyThermoSystem<7732-18-5, 7782-44-7,
             124-38-9, 7446-09-5, 7727-37-9, 7440-37-1>"
```

Input parameter value(s)

Inlet stream characterisation

Example
CALCULATE response: server → client

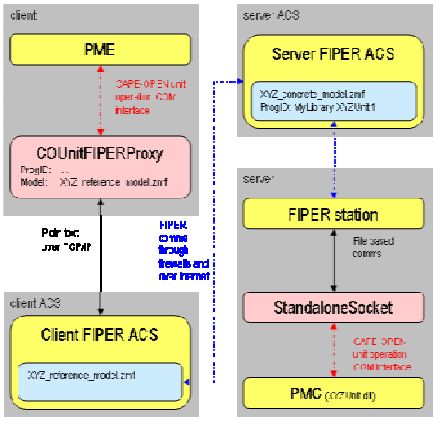
```
CALCULATE_RESPONSE

MASS

OUTPUT "FeedWaterFlow"
425

OUTLET      "GasOutlet"
MATERIAL    "PSEThermoLibrary.DummyThermoSystem<7732-18-5, 7782-44-7,
             124-38-9, 7446-09-5, 7727-37-9, 7440-37-1>"
PRESSURE    100000
TEMPERATURE 680.61000000000001
FLOW_V      [39.999999999999993, 19.999999999999996, 43.999999999999993,
             47.999999999999993, 350.00000000000006, 2]
FLOW_L      [0, 0, 0, 0, 0, 0]
```

Output parameter value(s)

Outlet stream characterisation

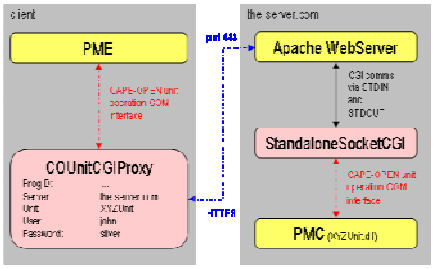
Communication middleware #1: FIPER

- Use Engineous' FIPER software as middleware
- Professional secure B2B solution
- All B2B connections occur between known machines (FIPER ACS)
- All interactions logged in FIPER D/B
- Load balancing as standard, specific units configured to run on specific machines



Communication middleware #2: CGI

- Use a simple web server with CGI as middleware
- Secured with HTTP 'basic authentication', server-side X.509 certificates and HTTPS protocol
- No additional software cost for middleware – works with Apache
- Only requires basic web admin knowledge to configure the server
- All interactions can be logged to file
- Possible to run CO Units through a web browser



Restrictions imposed by architecture

- A ‘duplicate’ thermo system/package is required on the server side
  - essential to avoid excessive communications
- Units must be able to operate without GUI
- Unit’s parameters/ports must not be interdependent
  - connecting a port or setting a parameter must not result in a change in the name, number, type, direction or specification of any port or parameter
- The unit must be stateless
  - it should not cache (in memory) the result of one calculation in order to service a subsequent calculation

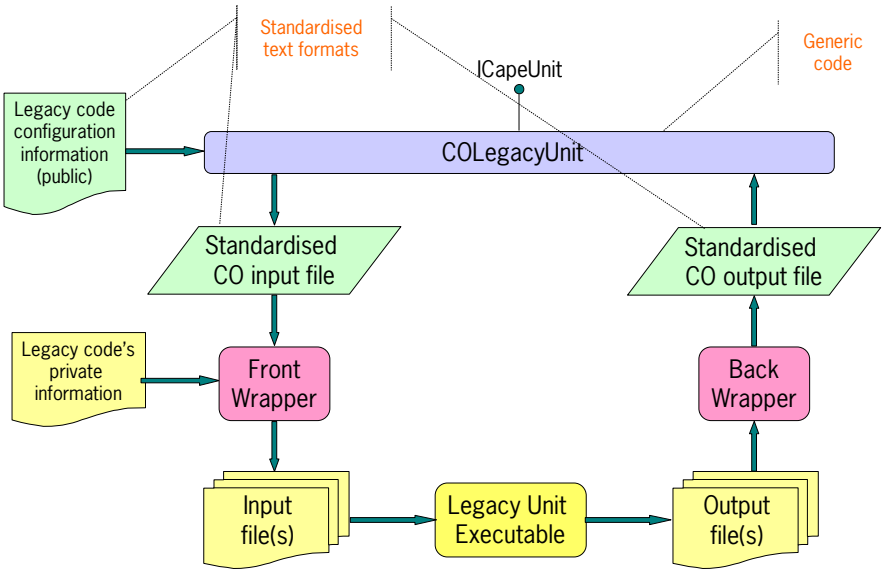
Wrapping legacy units for CAPE-OPEN

(A useful tool for those who are CAPE-OPEN unit operation wizard challenged)

Legacy codes

- Codes written in procedural computer languages
  - FORTRAN, C, C++, MATLAB, …
- Batch execution
  - codes involve no user interaction or interface
  - a binary executable – source code may not be available
  - all inputs read from input text file(s)
  - all output generated into output text file(s)
- Material streams contain predefined components

Overall architecture for legacy codes



The COLegacyUnit

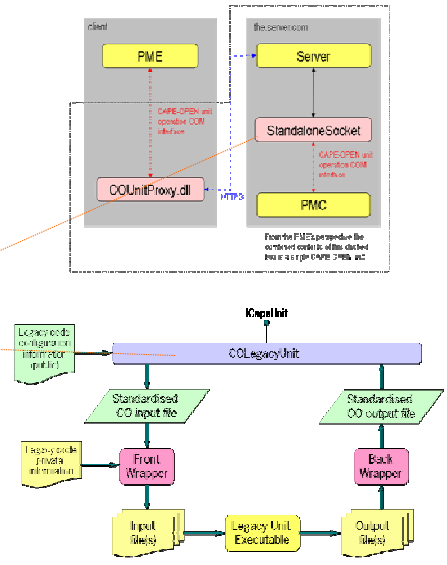
PSE

- Each legacy code is made available to a PME via a registered instance of COLegacyUnit
- The COLegacyUnit handles queries about parameters and ports using the information in the 'configuration' file
- The COLegacyUnit handles an ICapeUnit::Calculate() call by:
  - writing the 'input' file
  - launching the executable
  - reading the 'output' file

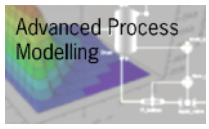
Support for legacy units on UNIX

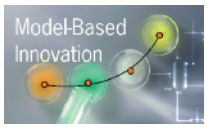
PSE

- Mechanism to allow legacy codes running on UNIX platforms to be accessed from PMEs running on MS Windows
- StandaloneLegacyUnitSocket
  - Java executable that runs on any system (including Windows) with Java 1.5 implementation
  - combines the behaviour of the StandaloneSocket with the COLegacyUnit
  - externally presents same text and file based interface as the StandaloneSocket
  - only works with legacy units
    - not a general CORBA CAPE-OPEN Unit socket

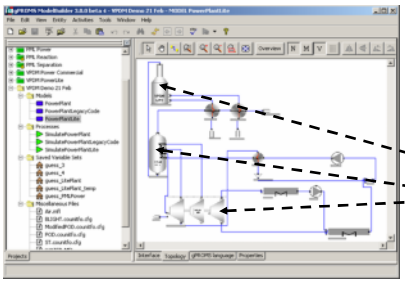


Conclusions





Conclusions



- Inter-organisational collaborative modelling
  - new paradigm required for distributed modelling
  - emphasis on security of IP
- CAPE-OPEN wrapping of legacy codes
  - allows use of codes within standard PMEs
  - key issue: numerical behaviour of legacy codes originally intended for "stand-alone" use only

Acknowledgements

- This work was partially funded by the UK Department of Trade and Industry under the Virtual Plant Demonstration Project (VPDM)
- The collaboration of the VPDM project consortium is gratefully acknowledged

