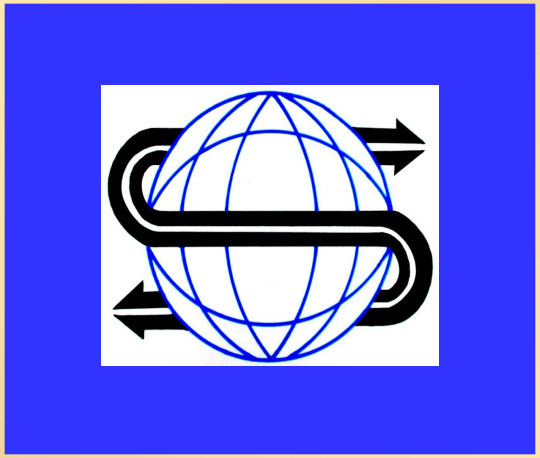


DALHOUSIE UNIVERSITY

Inspiring Minds

Recent Changes to the Optimization Services Project

H.I. Gassmann, Faculty of Management
J. Ma, Northwestern University
R.K. Martin, The University of Chicago

CORS/INFORMS, June 2009

Outline

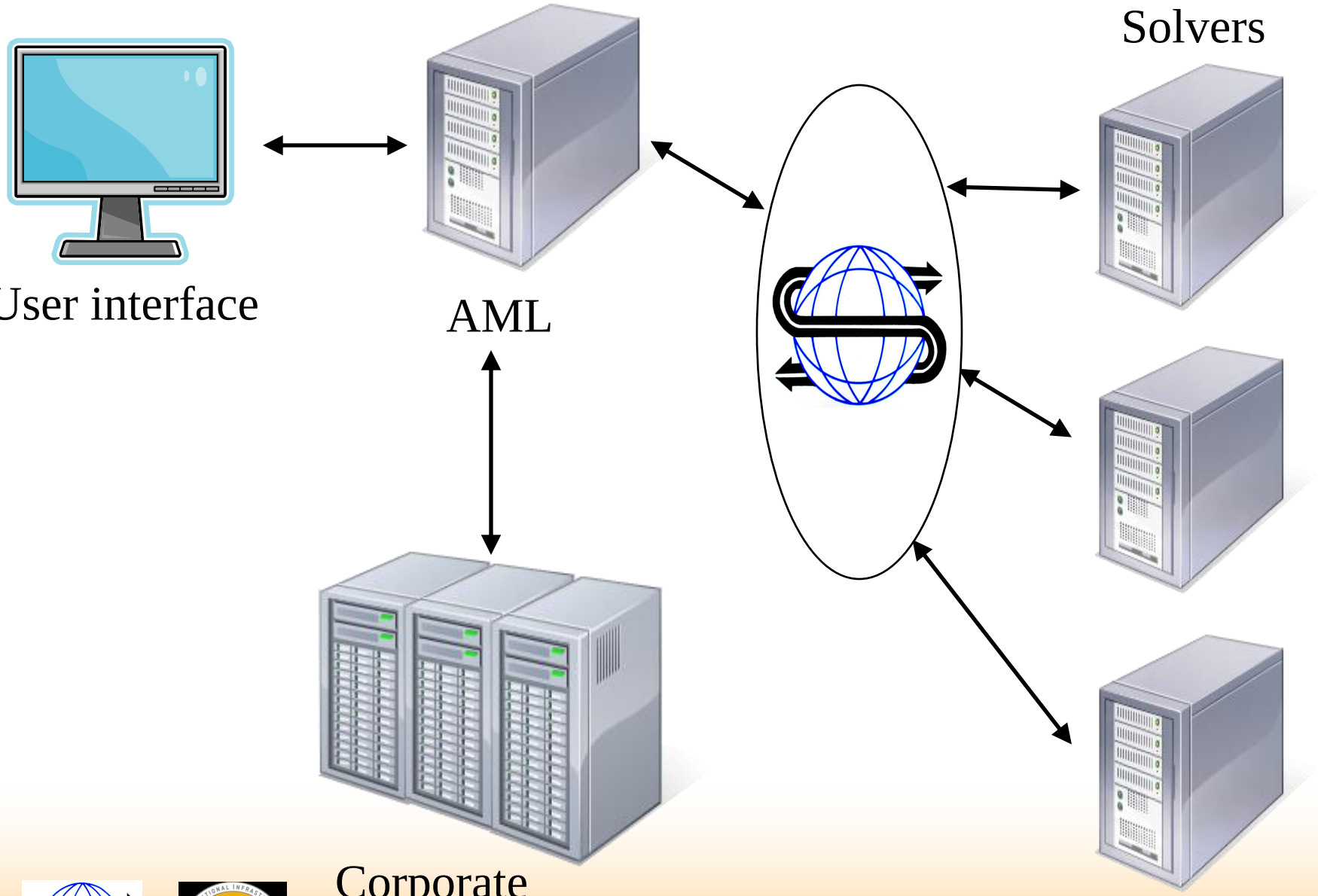
- Overview of OS
- OSiL – OS instance language
- OSoL – OS option language
- OSrL – OS result language
- Future plans

DALHOUSIE UNIVERSITY
Inspiring Minds

Optimization Services (OS)

- *A set of standards to facilitate communication between modeling languages, solvers, problem analyzers, simulation engines, and registry and discovery services in a distributed computing environment.*
- *Programming language, operating system, and hardware independent.*
- *Open and available for everyone in the OR community to use free of charge.*
- *Optimization should be as easy as hooking up to the network.*

DALHOUSIE UNIVERSITY
Inspiring Minds



DALHOUSIE UNIVERSITY
Inspiring Minds

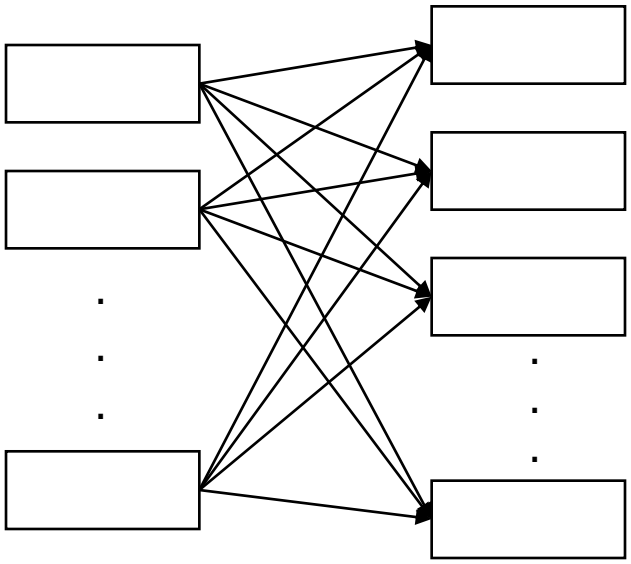
Optimization Services

Optimization services is needed because there is/are:

- Numerous modeling languages each with their own format for storing the underlying model.
- Numerous solvers each with their own application program interface (API).
- Numerous operating system, hardware, and programming language combinations.
- No standard for representing problem instances, especially nonlinear optimization instances.
- No real standard for registry and discovery services.

DALHOUSIE UNIVERSITY
Inspiring Minds

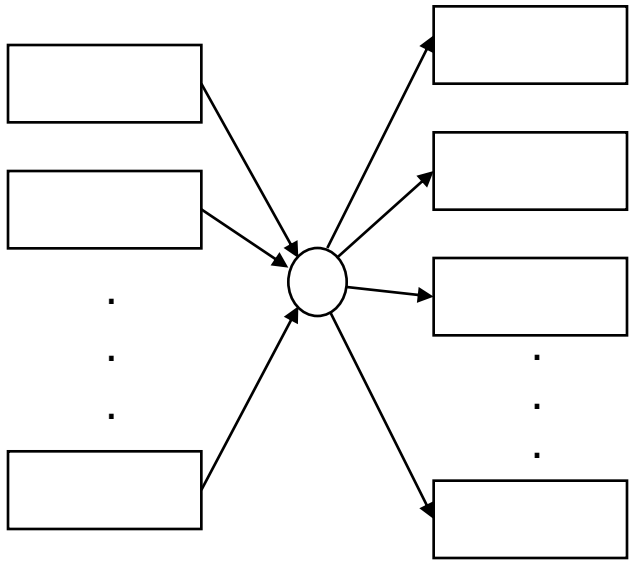
Why a standard interface?



Modelling systems

Solvers

*n***m* hook-ups



Modelling systems

Solvers

n+*m* hook-ups

DALHOUSIE UNIVERSITY
Inspiring Minds

What Is Optimization Services (OS)?

- A set of XML-based standards for representing information relevant to the practice of optimization, most importantly optimization instances (OSiL), optimization results (OSrL), and optimization solver options (OSoL).
- Open source libraries that support and implement many (eventually all) of the standards.
- A robust API for both solver algorithms and modeling systems. The API is for linear, integer, general nonlinear and stochastic programs.
- A command line executable OSSolverService for reading problem instances (in OSiL format, AMPL nl format, or MPS format) and calling a solver either locally or on a remote server.

DALHOUSIE UNIVERSITY
Inspiring Minds

What Is Optimization Services (OS)?

- Utilities that convert MPS files and AMPL nl files into the OSiL XML-based format.
- Standards that facilitate the communication between clients and optimization solvers using Web Services and libraries that support these standards.
- An executable program OSAmplClient that is designed to work with the AMPL modeling language. OSAmplClient appears as a "solver" to AMPL and, based on options given in AMPL, contacts solvers either remotely or locally to solve instances created in AMPL.
- Server software that works with Apache Tomcat and Apache Axis. This software uses Web Services technology and acts as middleware between the client that creates the instance, and solver on the server that optimizes the instance and returns the result.

Solver support

- All versions of OS download with COIN-OR solvers
  - Clp
  - Cbc
  - Ipopt
  - Bonmin
  - Couenne
  - Symphony
- Additional support
  - Cplex
  - GLPK
  - Lindo

DALHOUSIE UNIVERSITY
Inspiring Minds

Main components of OS

- OSiL and OSInstance
- OSoL and OSOption
- OSrL and OSResult
- OSpL
- OSSolverService
- OSAmplClient

DALHOUSIE UNIVERSITY
Inspiring Minds

OSiL

- XML schema for mathematical programs
  - Linear
  - Integer
  - Nonlinear
  - Stochastic
  - Multiobjective
  - …

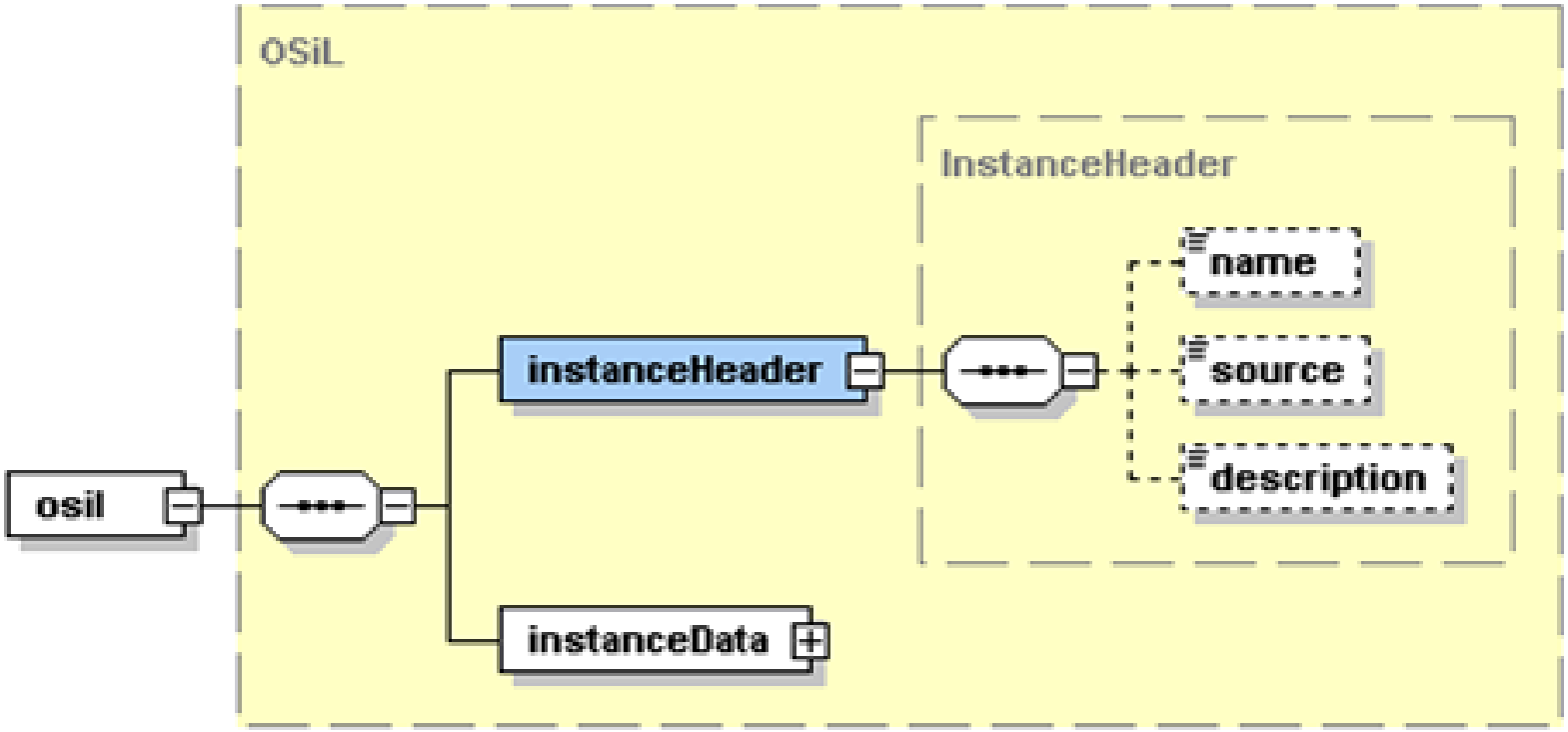
DALHOUSIE UNIVERSITY
Inspiring Minds

Why XML?

- Existing parsers to check syntax
- Easy to generate automatically
- Tree structure naturally mirrors expression trees for nonlinear functions
- Arbitrary precision and name space
- Automatic attribute checking (e.g., nonnegativity)
- Querying capabilities via XQuery
- Encryption standards being developed
- Easy integration into broader IT infrastructure

DALHOUSIE UNIVERSITY
Inspiring Minds

OSiL Schema – Header information

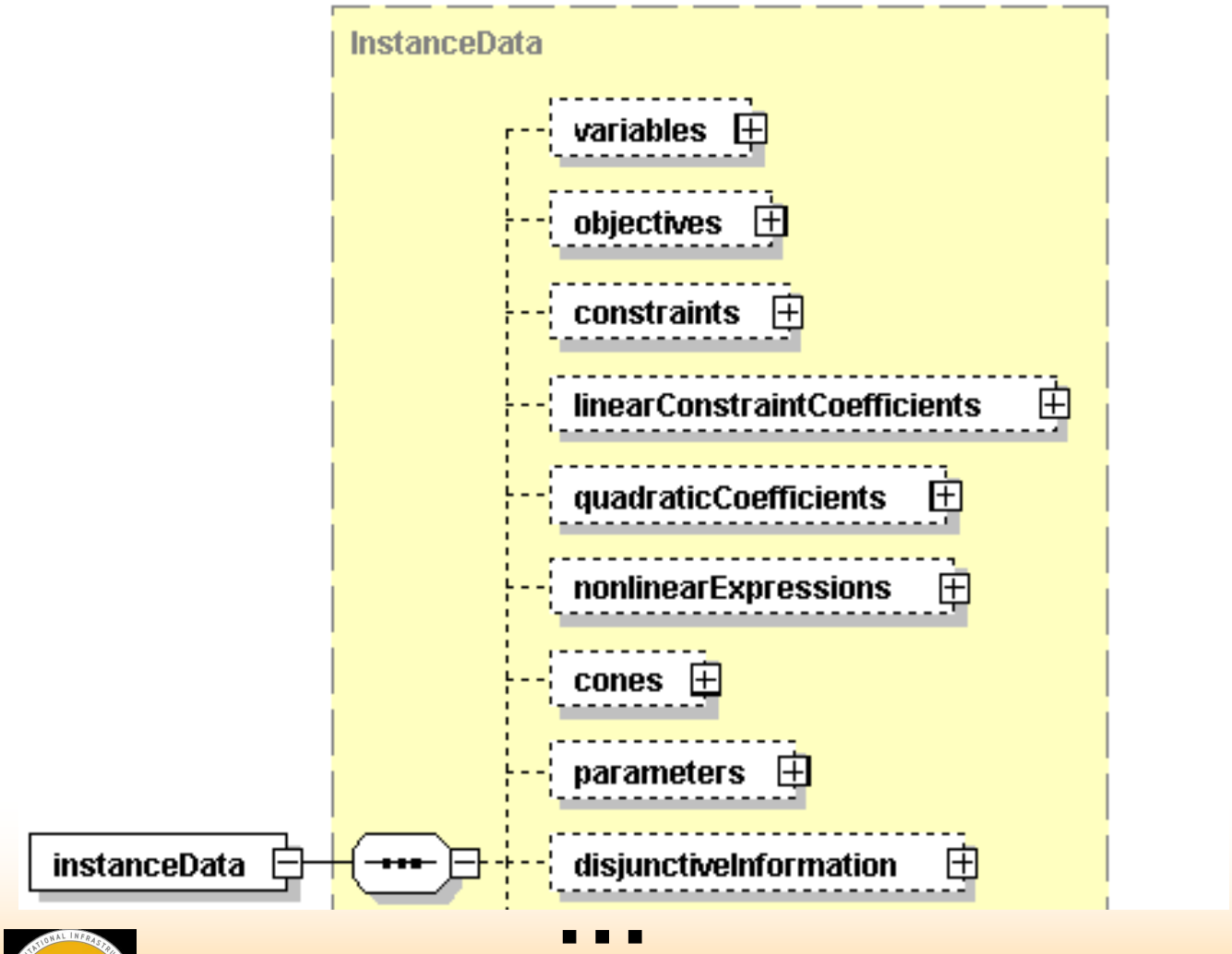


Header information – Example

```
<?xmlversion="1.0" encoding="UTF8"?>
<osil xmlns="os.optimizationservices.org"
      xmlns:xsi="htt://www.w3.org/2001/XMLSchemainstance"
      xsi:schemaLocation="os.optimizationservices.org
          http://www.optimizationervices.org/schemas/2.0/OSiL.xsd">
  <instanceHeader>
    <name>FinPlan</name>
     <source>
        Birge and Louveaux, Stochastic Programming
     </source>
     <description>
        Three-stage stochastic investment problem
     </description>
  </instanceHeader >
  <instanceData>
       ...
  </instanceData>
</osil>
```

DALHOUSIE UNIVERSITY
Inspiring Minds

OSiL Schema – Deterministic data



Instance data –Variables, objectives, constraints

```
<variables numberOfVariables="8">
   <var name="invest01" type="C" lb="0.0"/>
   <var name="invest02"/>
   <var name="invest11"/>
   <var name="invest12"/>
   <var name="invest21"/>
   <var name="invest22"/>
   <var name="w"/>
   <var name="u"/>
</variables>
<objectives numberOfObjectives="1">
   <obj maxOrMin="max" numberOfObjCoef= "2" lb="0.0">
      <coef idx="6"/>1.</coef>
      <coef idx="7"/>-4.</coef>
   </obj>
</objectives>
<constraints numberOfConstraints="4">
   <con name="budget0" lb="55" ub="55"/>
   <con name="budget1" lb="0" ub="0"/>
   <con name="budget2" lb="0" ub="0"/>
   <con name="budget3" lb="80" ub="80"/>
</constraints>
```

DALHOUSIE UNIVERSITY
Inspiring Minds

Instance data – Core matrix (sparse matrix form)

```
<linearConstraintCoefficients
        numberOfValues="14">
  <start>
    <el>0</el>
    <el>2</el>
    <el>4</el>
    <el>6</el>
    <el>8</el>
    <el>10</el>
    <el>12</el>
    <el>13</el>
    <el>14</el>
  </start>
  <rowIdx>
    <el>0</el>
    <el>1</el>
    <el>0</el>
    <el>1</el>
    <el>1</el>
    <el>2</el>
    <el>1</el>
    <el>2</el>
    <el>2</el>
    <el>3</el>
    <el>2</el>
    <el>3</el>
    <el>3</el>
    <el>3</el>
  </rowIdx>
  <value>
    <el>1</el>
    <el>1.25</el>
    <el>1</el>
    <el>1.14</el>
    <el>1</el>
    <el>1.25</el>
    <el>1</el>
    <el>1.14</el>
    <el>1</el>
    <el>1.25</el>
    <el>1</el>
    <el>1.14</el>
    <el>1</el>
    <el>-1</el>
  </value>
```

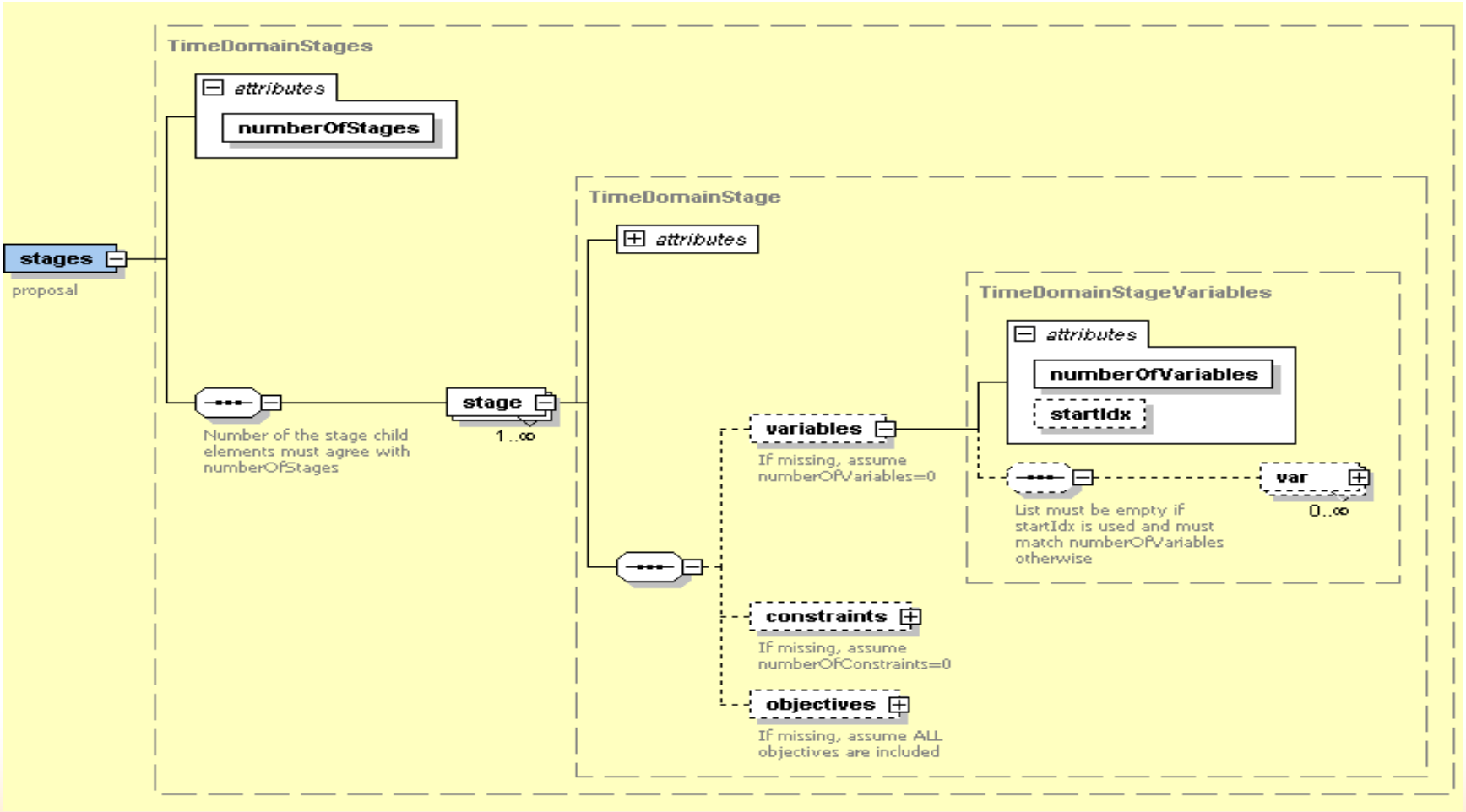
DALHOUSIE UNIVERSITY
Inspiring Minds

Representation of uncertainty

- Explicit event trees
  - Scenario formulation
  - Only record data items that differ from parent scenario
- Implicit trees (distribution-based formulation)
  - Continuous or discrete random variables
  - Linked to problem coefficients via transformations
  - Incomplete information
- Probabilistic constraints
  - Simple chance constraints
  - Joint chance constraints
- Robust formulations

DALHOUSIE UNIVERSITY
Inspiring Minds

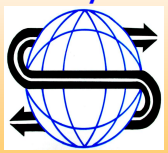
OSiL Schema – Dynamic structure



DALHOUSIE UNIVERSITY
Inspiring Minds

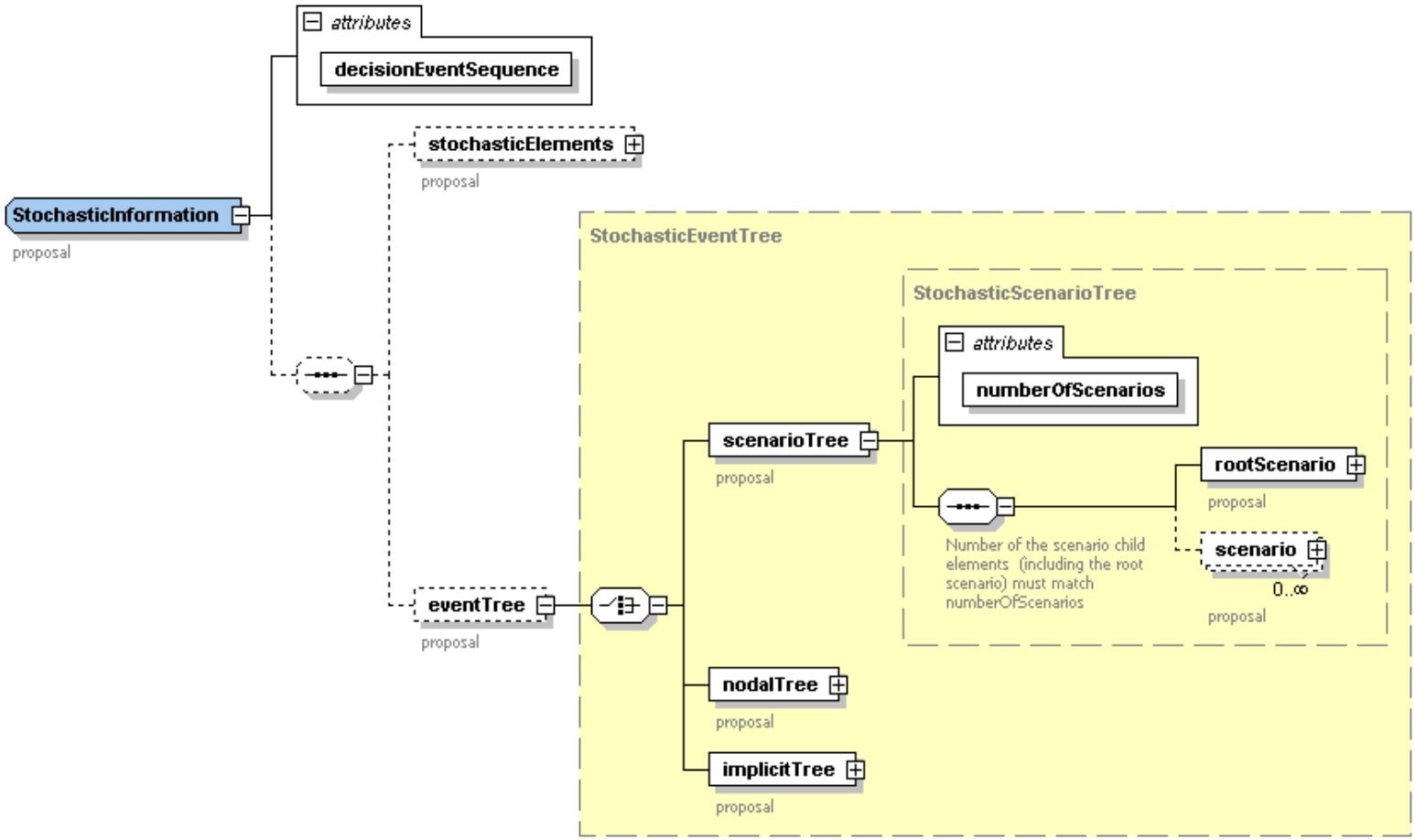
Dynamic information – Example

```
<stages numberOfStages="4">
   <stage>
      <variables numberOfVariables="2" startIdx="0"/>
      <constraints numberOfConstraints="1" startIdx="0"/>
   </stage>
   <stage>
      <variables numberOfVariables="2" startIdx="2"/>
      <constraints numberOfConstraints="1" startIdx="1"/>
   </stage>
   <stage>
      <variables numberOfVariables="2" startIdx="4"/>
      <constraints numberOfConstraints="1" startIdx="2"/>
   </stage>
   <stage>
      <variables numberOfVariables="2">
         <var idx="6">     <var idx="7">
      </variables>
      <constraints numberOfConstraints="1" startIdx="3"/>
   </stage>
</stages>
```



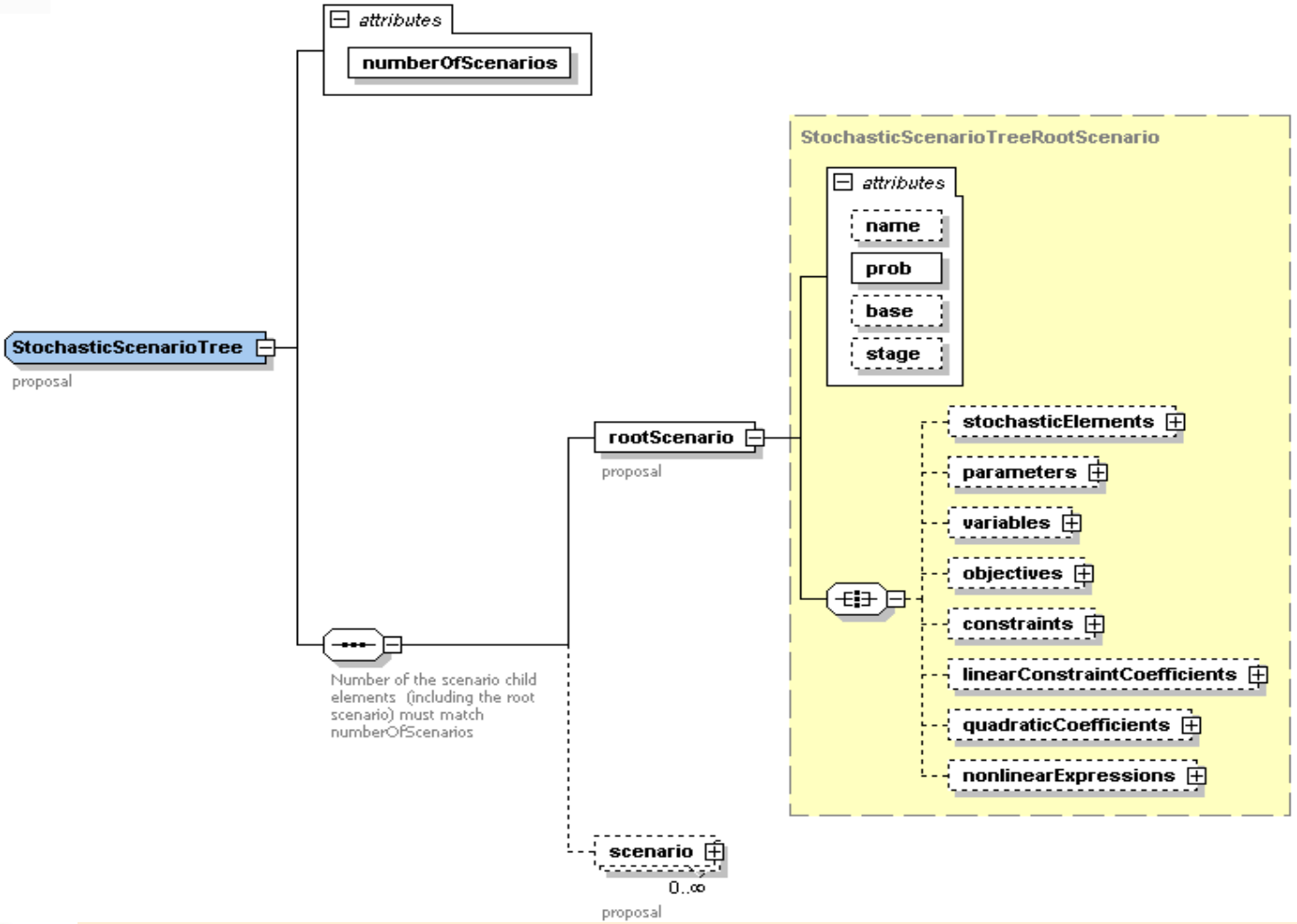
DALHOUSIE UNIVERSITY
Inspiring Minds

Explicit and implicit event trees



DALHOUSIE UNIVERSITY
Inspiring Minds

Scenario trees



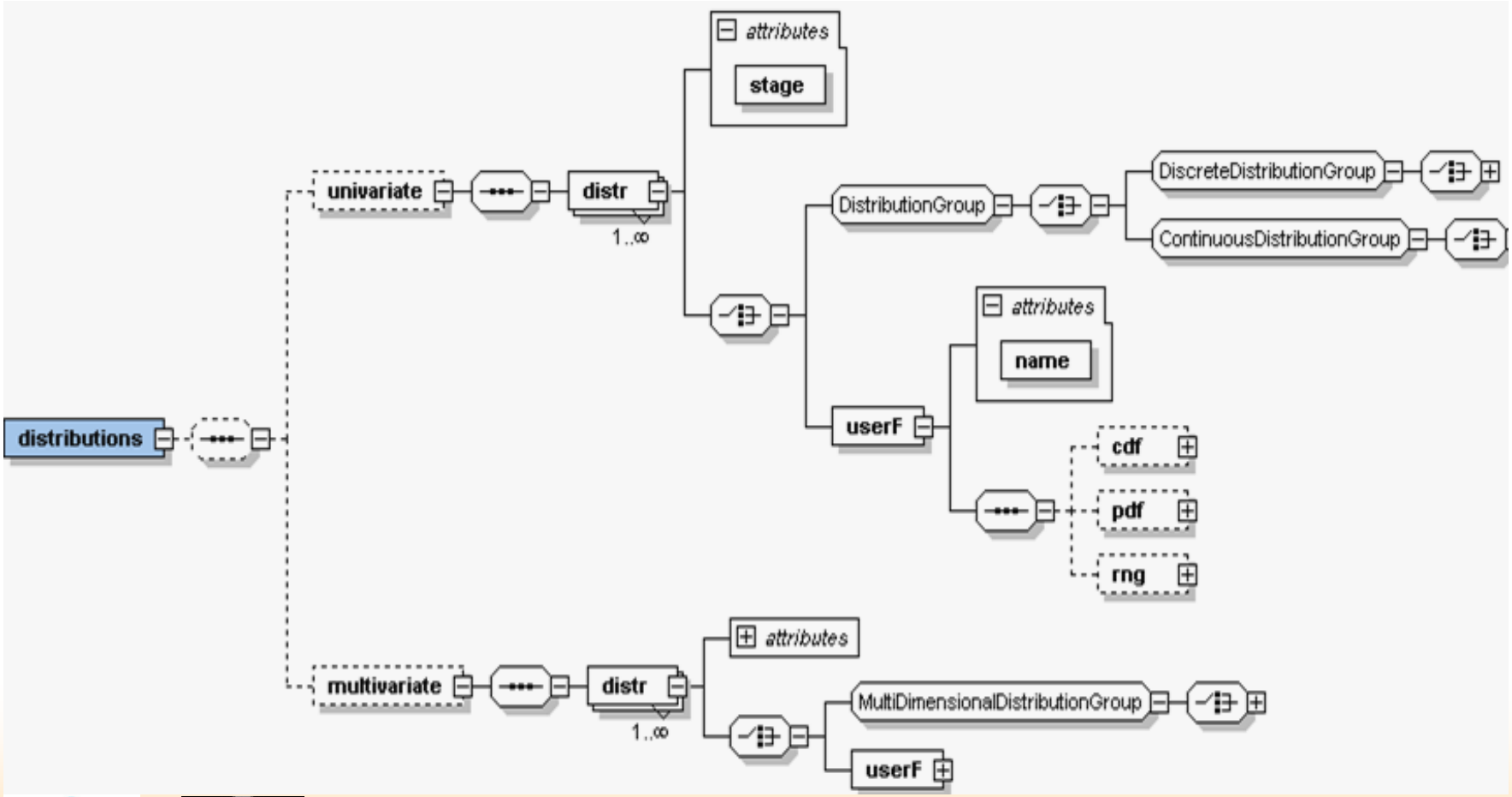
DALHOUSIE UNIVERSITY
Inspiring Minds

Scenario tree – Example

```
<stochasticInformation
        decisionEvenSequence="DecisionAfterEvent">
   <eventTree>
      <scenarioTree numberOfScenarios="8">
         <rootScenario prob="1" stage="0"/>
         <scenario prob="0.5" stage="3" parent="0">
            <linearConstraintCoefficients>
               <el rowIdx="3" colIdx="4">1.06</el>
               <el rowIdx="3" colIdx="5">1.12</el>
            </linearConstraintCoefficients>
         </scenario>
         <scenario prob="0.5" stage="2" parent="0">
           ...
```

DALHOUSIE UNIVERSITY
Inspiring Minds

Distributions (implicit tree)



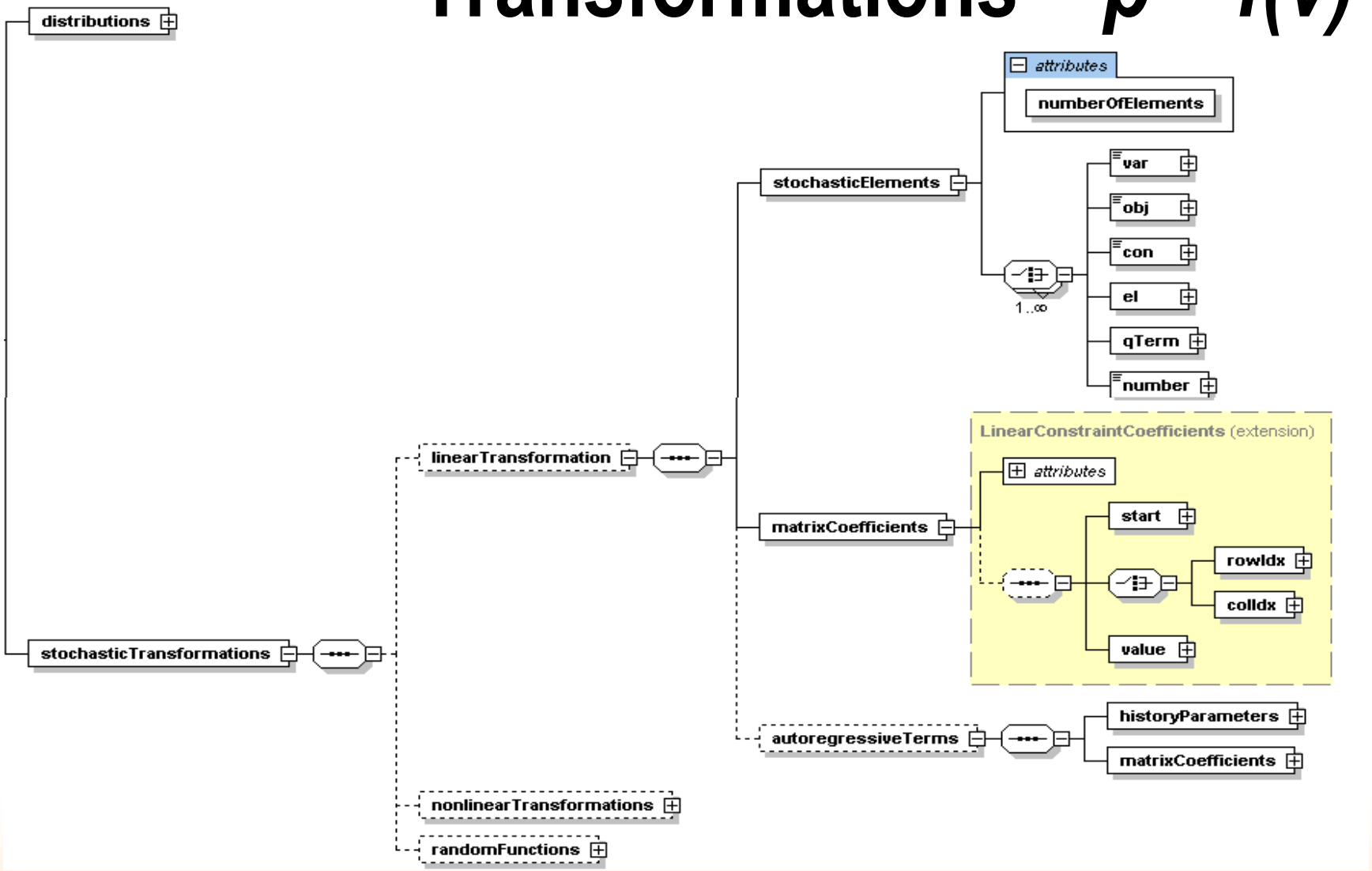
DALHOUSIE UNIVERSITY
Inspiring Minds

Discrete random vector

```
<distributions>
   <multivariate>
      <distr stage="1">
         <multiDimensionalDistributionGroup>
            <multivariateDiscrete>
               <scenario>
                  <prob>0.5</prob>
                  <el>1.25</el>
                  <el>1.14</el>
               </scenario>
               <scenario>
                  <prob>0.5</prob>
                  <el>1.06</el>
                  <el>1.12</el>
               </scenario>
            </multivariateDiscrete>
         </multiDimensionalDistributionGroup>
      </distr>
      ...
   </multivariate>
</distributions>
```

DALHOUSIE UNIVERSITY
Inspiring Minds

Transformations – $p = f(v)$



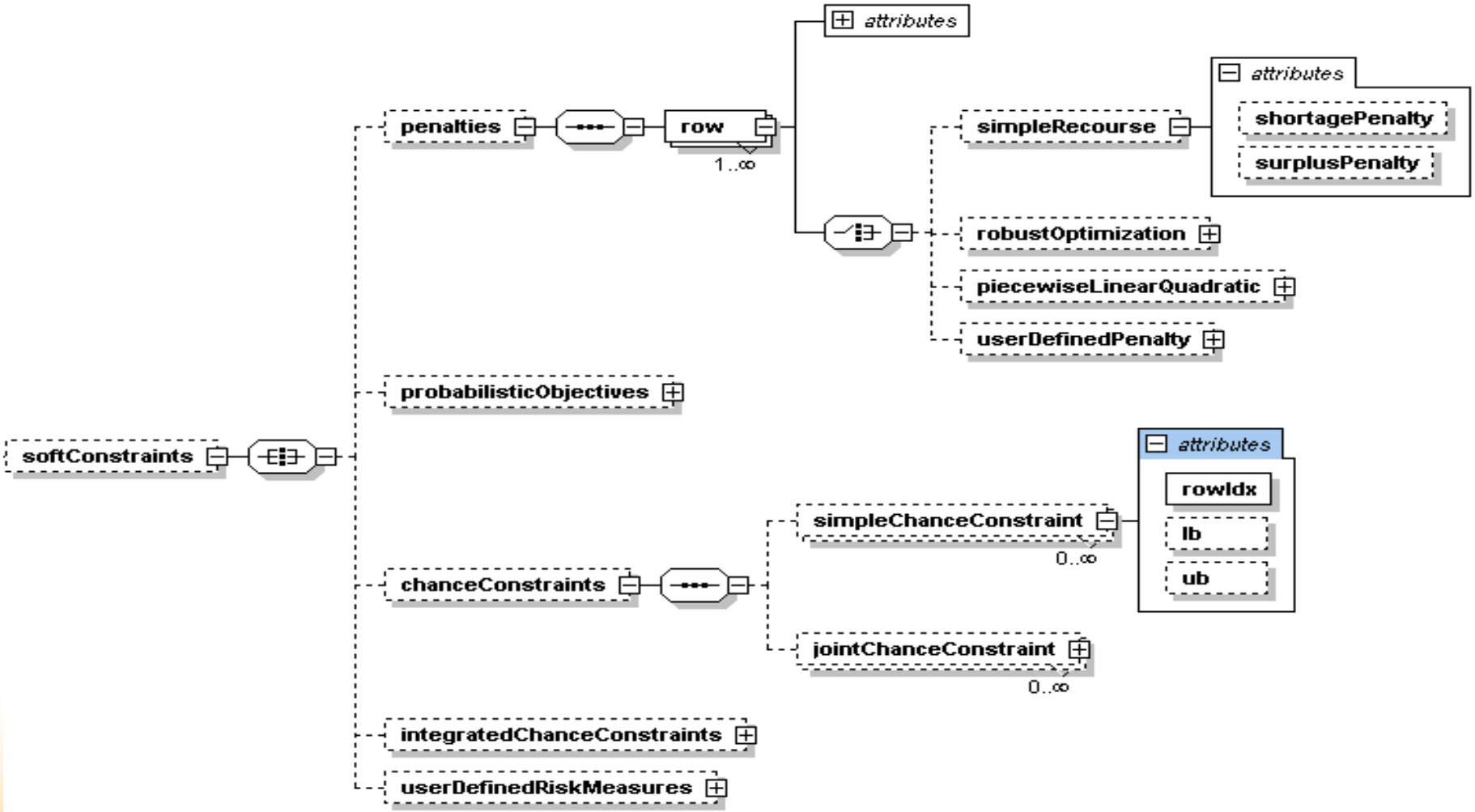
DALHOUSIE UNIVERSITY
Inspiring Minds

Linear transformation – Example

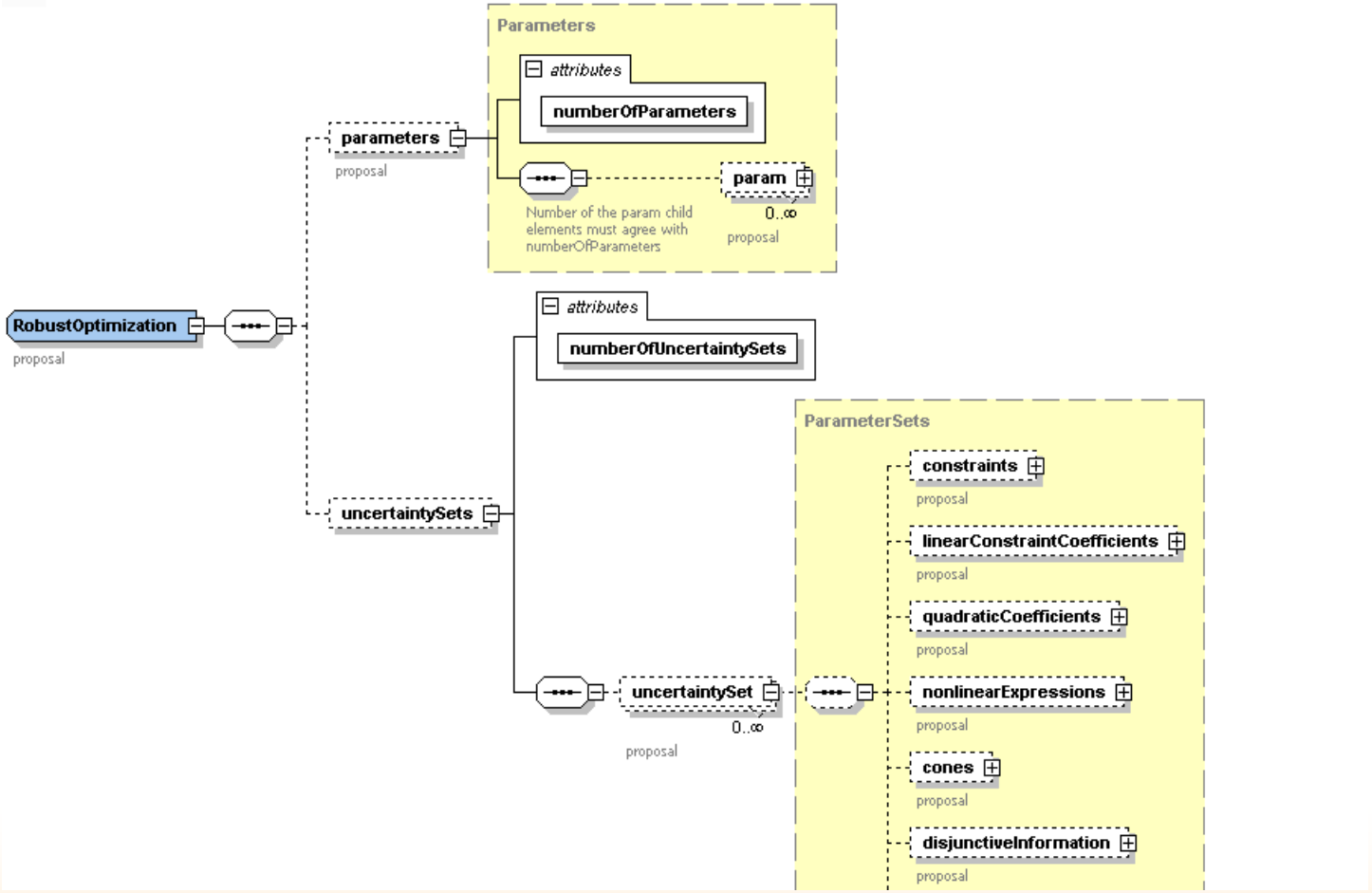
```
<stochasticTransformation>
   <linearTransformation>
      <stochasticElements
            numberOfElements="6">
         <el rowIdx="1" colIdx="0"/>
         <el rowIdx="1" colIdx="1"/>
         <el rowIdx="2" colIdx="2"/>
         <el rowIdx="2" colIdx="3"/>
         <el rowIdx="3" colIdx="4"/>
         <el rowIdx="3" colIdx="5"/>
      </stochasticElements>
      <matrixCoefficients
            numberOfElements="6">
         <start>
            <el>0</el>
            <el>1</el>
            <el>2</el>
            <el>3</el>
            <el>4</el>
            <el>5</el>
            <el>6</el>
         </start>
         <rowIdx>
            <el>0</el>
            <el>1</el>
            <el>2</el>
            <el>3</el>
            <el>4</el>
            <el>1</el>
         </rowIdx>
         <value>
            <el mult="6">1.0</el>
         </value>
      </matrixCoefficients>
   </linearTransformation>
</stochasticTransformation>
```

DALHOUSIE UNIVERSITY
Inspiring Minds

Penalties and probabilistic constraints



Robust optimization



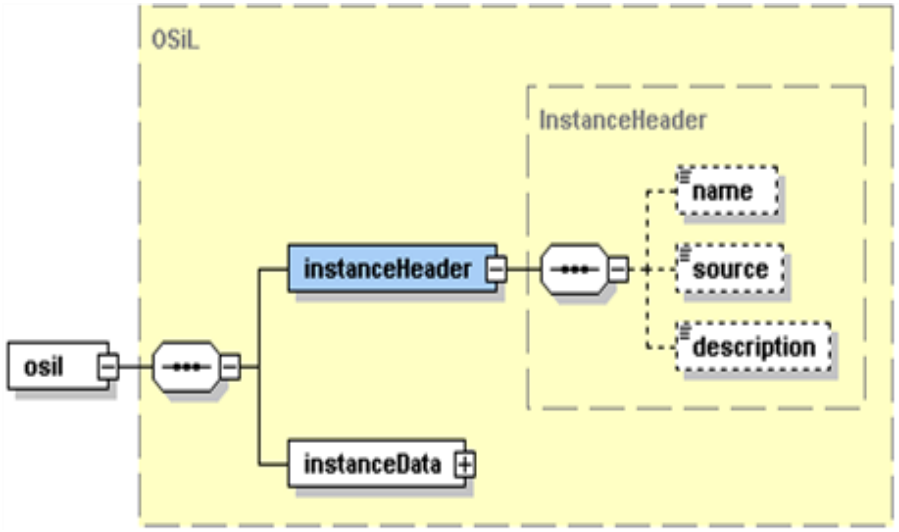
Capabilities

- Arbitrary nonlinear expressions
- Arbitrary distributions
- Scenario trees
- Stochastic problem dimensions
- Simple recourse
- Soft constraints with arbitrary penalties
- Probabilistic constraints
- Arbitrary moment constraints

DALHOUSIE UNIVERSITY
Inspiring Minds

OSInstance: In-memory representation

- XML elements correspond to C++ classes
- Child elements mapped as member classes




```
class OSInstance{
public:
   OSInstance();
   InstanceHeader *instanceHeader;
   InstanceData *instanceData;
}; // class OSInstance
```

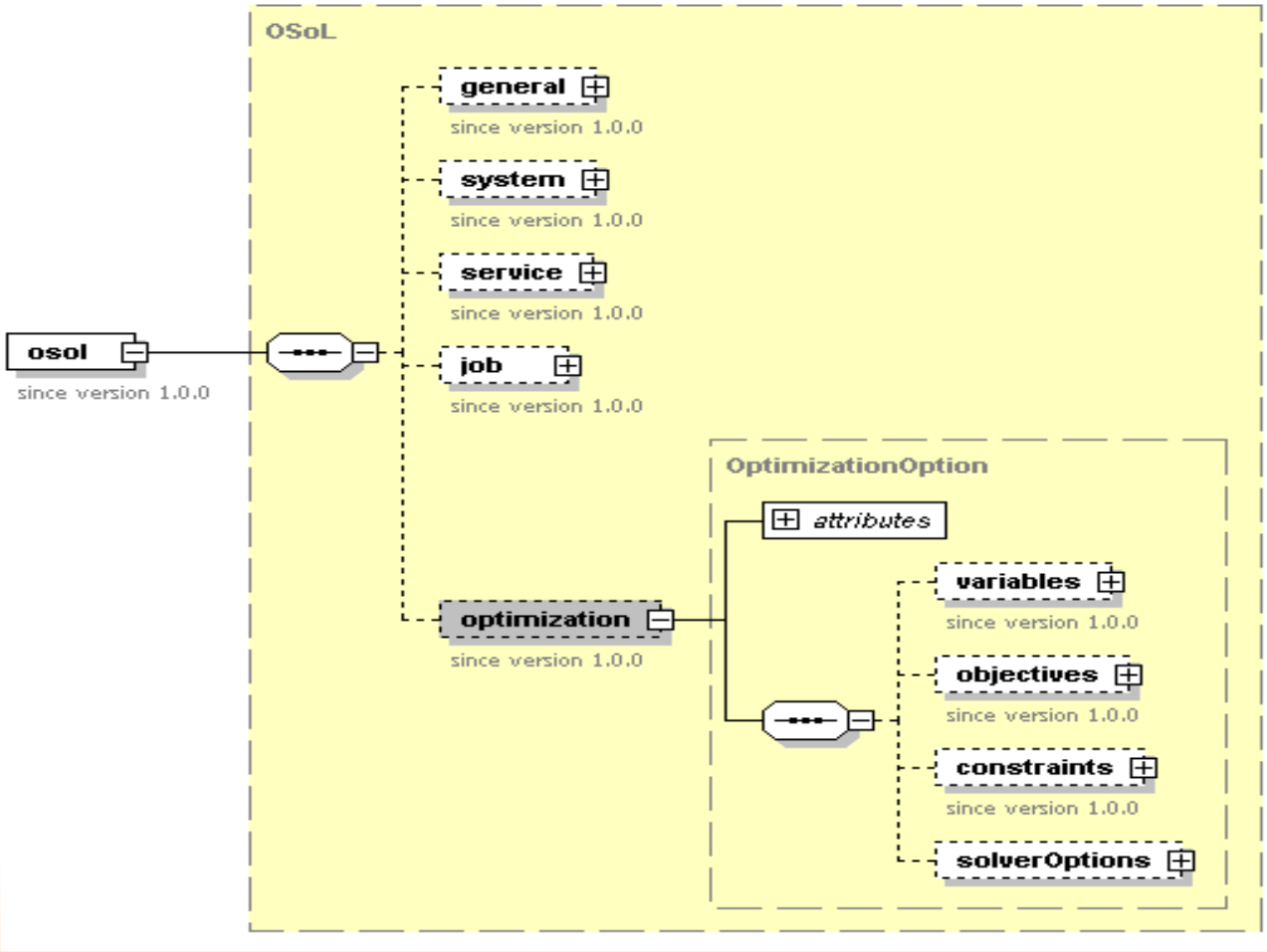
- set(), get() and calculate() methods

OSoL – OS option language

- Solver options
- Initializations of variables
- System requirements
- Job parameters
- In-memory representation: `OSOption`
- API: `get(), set(), add()` methods

DALHOUSIE UNIVERSITY
Inspiring Minds

OSoL schema



DALHOUSIE UNIVERSITY
Inspiring Minds

Sample .osol file

```
<?xml version="1.0" encoding="UTF-8"?>
<osol xmlns="os.optimizationservices.org"
   xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
   xsi:schemaLocation="os.optimizationservices.org
   http://www.optimizationservices.org/schemas/2.0/OSoL.xsd">
    <optimization numberOfVariables="2">
        <variables>
            <initialVariableValues numberOfVar="2">
                <var idx="0" value="5."/>    <var idx="1" value="5."/>
            </initialVariableValues>
        </variables>
        <solverOptions numberOfSolverOptions="3">
            <solverOption name="tol" solver="ipopt" type="numeric"
                 value="1.e-9"/>
            <solverOption name="print_level" solver="ipopt"
                 type="integer" value="5"/>
            <solverOption name="max_iter" solver="ipopt" type="integer"
                 value="2000"/>
        </solverOptions>
    </optimization>
</osol>
```

DALHOUSIE UNIVERSITY
Inspiring Minds

OSrL and OSResult

- Result of the optimization
  - Solution status
  - Statistics
  - Value of primal and dual variables
- Can be displayed in a browser

DALHOUSIE UNIVERSITY
Inspiring Minds

Sample result file

```
<?xml version="1.0" encoding="UTF-8"?><?xml-stylesheet type="text/xsl"
     href="../stylesheets/OSrL.xslt"?>
<osrl xmlns="os.optimizationservices.org"
     xmlns:xsi=http://www.w3.org/2001/XMLSchema-instance
     xsi:schemaLocation="os.optimizationservices.org
     http://www.optimizationservices.org/schemas/2.0/OSrL.xsd" >
  <general>
    <generalStatus type="normal"/>
    <serviceName>Ipopt solver service</serviceName>
    <instanceName>Original Rosenbrock</instanceName>
    <message>Ipopt solver finishes to the end.</message>
  </general>
  <optimization numberOfSolutions="1" numberOfVariables="2"
     numberOfConstraints="0" numberOfObjectives="1">
    <solution targetObjectiveIdx="-1">
      <status type="locallyOptimal" description="SUCCESS[IPOPT]:
        Algorithm terminated normally at a locally optimal point,
        satisfying the convergence tolerances."/>
      <variables numberOfOtherVariableResults="2">
        <values numberOfVar="2">
          <var idx="0">1.0000000011552117</var>
          <var idx="1">1.0000000023142723</var>
        </values>
```

DALHOUSIE UNIVERSITY
Inspiring Minds

Sample result file (cont'd)

```
        <other numberOfVar="2" name="varL"
             description="Lagrange Multiplier on the Variable Lower Bound">
          <var idx="0">7.701488100457089e-10</var>
          <var idx="1">7.701498562828543e-10</var>
        </other>
        <other numberOfVar="2" name="varU"
             description="Lagrange Multiplier on the Variable Upper Bound">
          <var idx="0">0</var>
          <var idx="1">0</var>
        </other>
      </variables>
      <objectives >
        <values numberOfObj="1">
          <obj idx="-1">1.3359955006550299e-18</obj>
        </values>
      </objectives>
    </solution>
  </optimization>
</osrl>
```

DALHOUSIE UNIVERSITY
Inspiring Minds

Current status and future plans

- Changes to OSoL and OSrL schemas and API
- Version 2.0 released this week
- Stochastic extensions to be finalized
- Proof of concept:
  - Generate and solve deterministic equivalent
  - Link to MSLiP
  - Link to sampling-based solvers

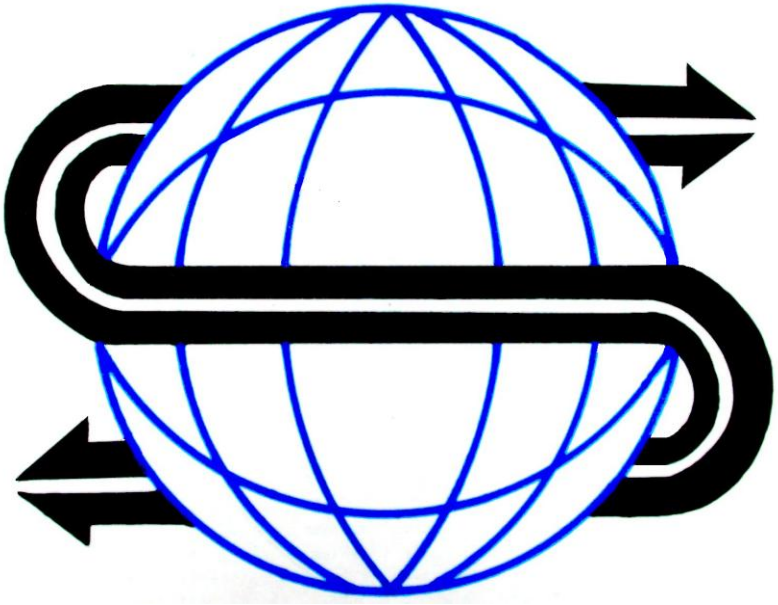
DALHOUSIE UNIVERSITY
Inspiring Minds

How to get OS

- Binaries
  - http://www.coin-or.org/download/binary/OS
    - OS-1.0.0-win32-msvs-v8.zip
    - OS-1.1.1-linux-x86_64-icc10.1.tgz
- Source code
  - http://www.coin-or.org/download/source/OS/
    - OS-1.1.1.tgz
    - OS-1.1.1.zip

DALHOUSIE UNIVERSITY
Inspiring Minds

QUESTIONS?



http://myweb.dal.ca/gassmann

http://www.optimizationservices.org

http://www.coin-or.org/projects/OS.xml

Horand.Gassmann@dal.ca

DALHOUSIE UNIVERSITY
Inspiring Minds