GAMS

GAMS MIRO

Introduction to a web interface for your GAMS models

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GAMS

Model Stages

Design

Build

Deploy

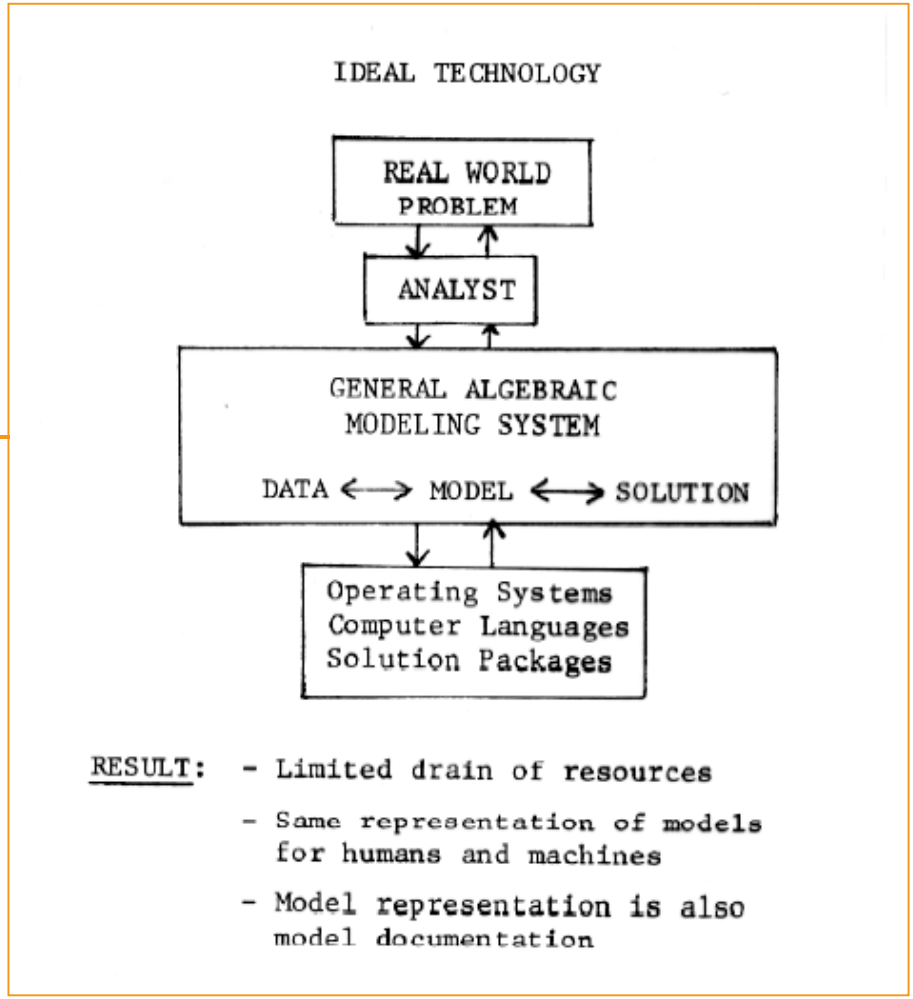
GAMS: building models

History

Design principles

1976 – A World Bank Slide

The Vision



GAMS came into being!

Simple Example

Indices:

i = plants
j = markets

Given Data:

a_i = supply of commodity of plant i (in cases)
b_j = demand for commodity at market j
c_{ij} = cost per unit shipment between plant i and market j

Decision Variables:

x_{ij} = amount of commodity to ship from plant i to market j
where $x_{ij} \geq 0$, for all i, j

Constraints:

Observe supply limit at plant i: $\sum_j x_{ij} \leq a_i$ for all i (cases)
Satisfy demand at market j: $\sum_i x_{ij} \geq b_j$ for all j (cases)
Objective Function: Minimize $\sum_i \sum_j c_{ij} x_{ij}$ ($K)

```
Sets
     i   canning plants   / seattle, san-diego /
     j   markets          / new-york, chicago, topeka / ;
Parameters
     a(i)  capacity of plant i in cases
     b(j)  demand at market j in cases
     c(i,j)  transport cost in thousands of dollars per case ;
Variables
     x(i,j)  shipment quantities in cases
     z       total transportation costs in thousands of dollars ;
Equations
     cost        define objective function
     supply(i)   observe supply limit at plant i
     demand(j)   satisfy demand at market j ;

cost ..        z  =e=  sum((i,j), c(i,j)*x(i,j)) ;
supply(i) ..   sum(j, x(i,j))  =l=  a(i) ;
demand(j) ..   sum(i, x(i,j))  =g=  b(j) ;

Model transport /all/ ;
```

What did this give us?

- Simplified model development & maintenance
- Increased productivity tremendously
- Made mathematical optimization available to a broader audience (domain experts)

2012 INFORMS Impact Prize:

"The awardees were trailblazers in developing the five most important algebraic modeling languages: AIMMS, AMPL, GAMS, LINDO/LINGO and MPL. …"

Independence of Model and Solver

One environment for a wide range of model types and solvers

All major commercial LP/MIP solver

Open Source Solver (COIN)

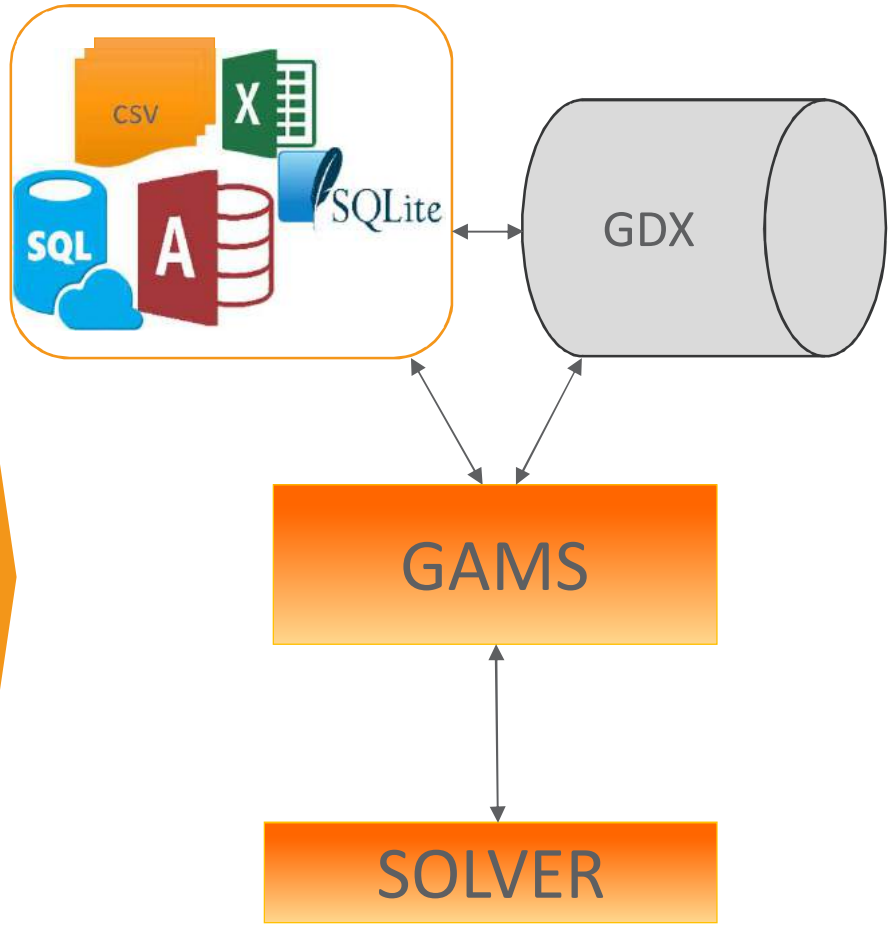
Also solver for NLP, MINLP, global, and stochastic optimization

Switching between solvers with one line of code!

Independence of Model and Data

- Declarative Modeling
- ASCII: Initial model development

- GDX: Data layer ("contract") between GAMS and applications
  - Platform independent
  - No license required
  - Direct GDX interfaces and general API
  - …



Independence of Model and User Interface

API's

- *Low Level*
- **Object Oriented**: .Net, Java, Python, C++
- No modeling capability: Model is written in GAMS
- Wrapper class that encapsulates a GAMS model

MIRO backstory

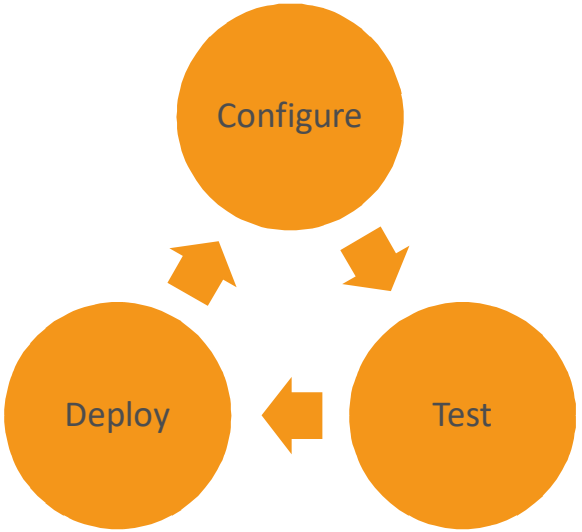
Client request for a web deployment environment
Benefits of R/Shiny

Motivation

Separation of Tasks:

- Modeling work
  - → AMLs are powerful tools for developing solver-independent optimization models
  - → GAMS for modeling and optimization
- Intuitive deployment and visualization are becoming increasingly important
  - → End-users of optimization software are very often not modeling experts
  - → Need for easy-to-use tool to visualize data and compare results

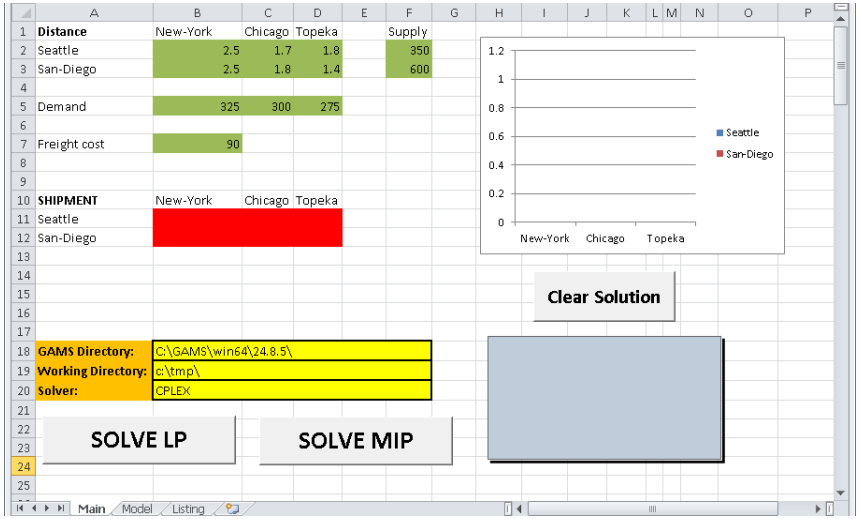
→ Current deployment possibilities are not satisfactory for everyone



Deployment of GAMS models
current possibilities

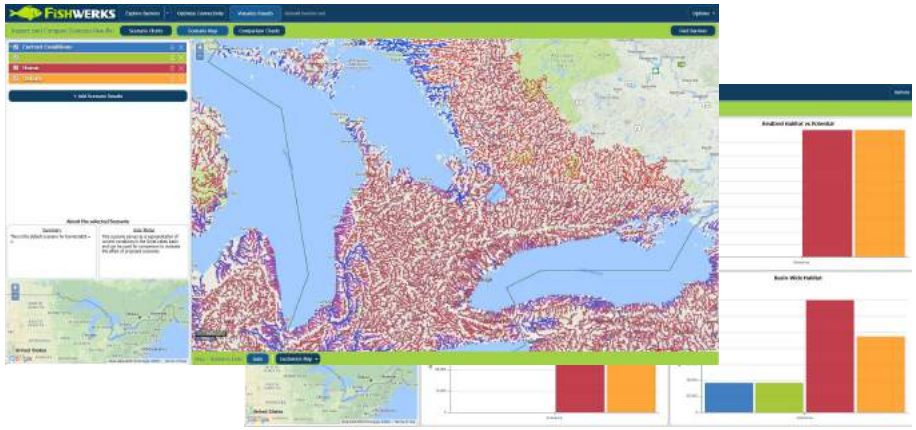
Expert level APIs

- GDX, OPT, GAMSX, GMO, …
- High performance and flexibility
- Automatically generated imperative APIs for several languages (C, C++, C#, Delphi, Java, Python, VBA, …)



Object Oriented APIs

- GAMS comes with several OO APIs (Python, Java, C++, C#, …) to develop applications



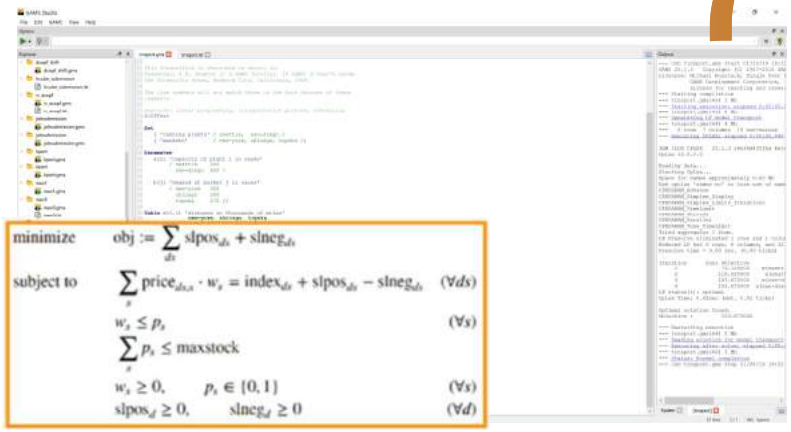
→ Programming required to build your applications

GAMS MIRO

Model Interface with Rapid Orchestration

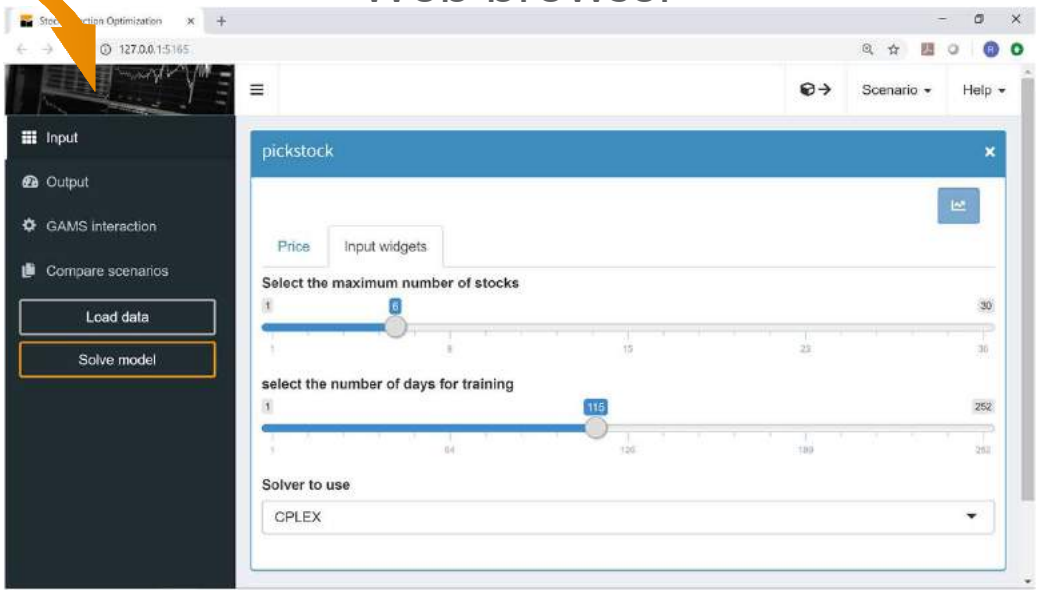
Click to deploy

Develop GAMS model



$$\begin{aligned}
\text{minimize} \quad & \text{obj} := \sum_{ds} \text{slpos}_{ds} + \text{slneg}_{ds} \\
\text{subject to} \quad & \sum_{s} \text{price}_{ds,s} \cdot w_s = \text{index}_{ds} + \text{slpos}_{ds} - \text{slneg}_{ds} \quad (\forall ds) \\
& w_s \le p_s \quad (\forall s) \\
& \sum_{s} p_s \le \text{maxstock} \\
& w_s \ge 0, \qquad p_s \in \{0,1\} \quad (\forall s) \\
& \text{slpos}_d \ge 0, \qquad \text{slneg}_d \ge 0 \quad (\forall d)
\end{aligned}$$

Web browser

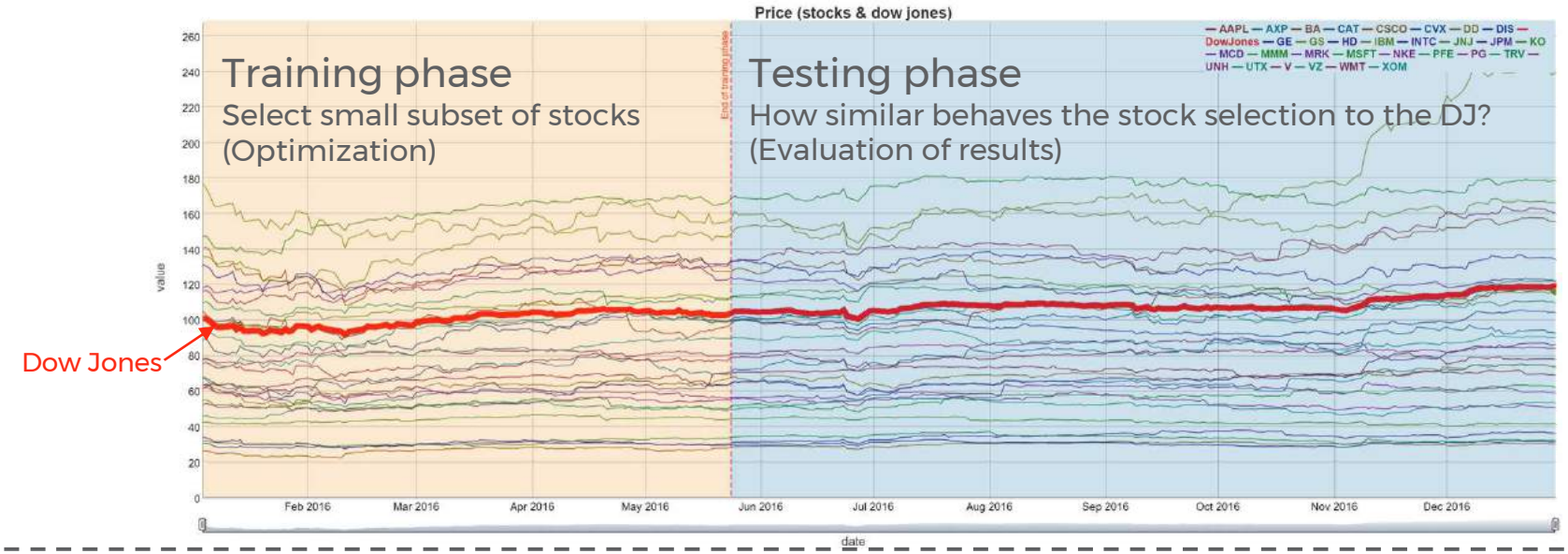


- ✓ Web interface for GAMS models
- ✓ Usage via web browser
- ✓ GAMS as a black box
- ✓ Focus on automated deployment
- ✓ Configuration instead of programming

Example

Model: Pickstock

Model: *Pickstock*



- **Data**: Performance of all shares of the Dow Jones index over a period of 1 year
- **Goal**: Find a small selection of stocks that follows the Dow Jones as good as possible
- **Optimization model**: Select a subset (≤ `maxstock`) of Dow Jones stocks, along with weights, so that this portfolio behaves similarly to the overall index (in the training phase)

$$\text{minimize} \quad \text{obj} := \sum_{ds} \text{slpos}_{ds} + \text{slneg}_{ds}$$

$$\text{subject to} \quad \sum_{s} \text{price}_{ds,s} \cdot w_s = \text{index}_{ds} + \text{slpos}_{ds} - \text{slneg}_{ds} \qquad (\forall ds)$$

$$w_s \le p_s \qquad (\forall s)$$

$$\sum_{s} p_s \le \text{maxstock}$$

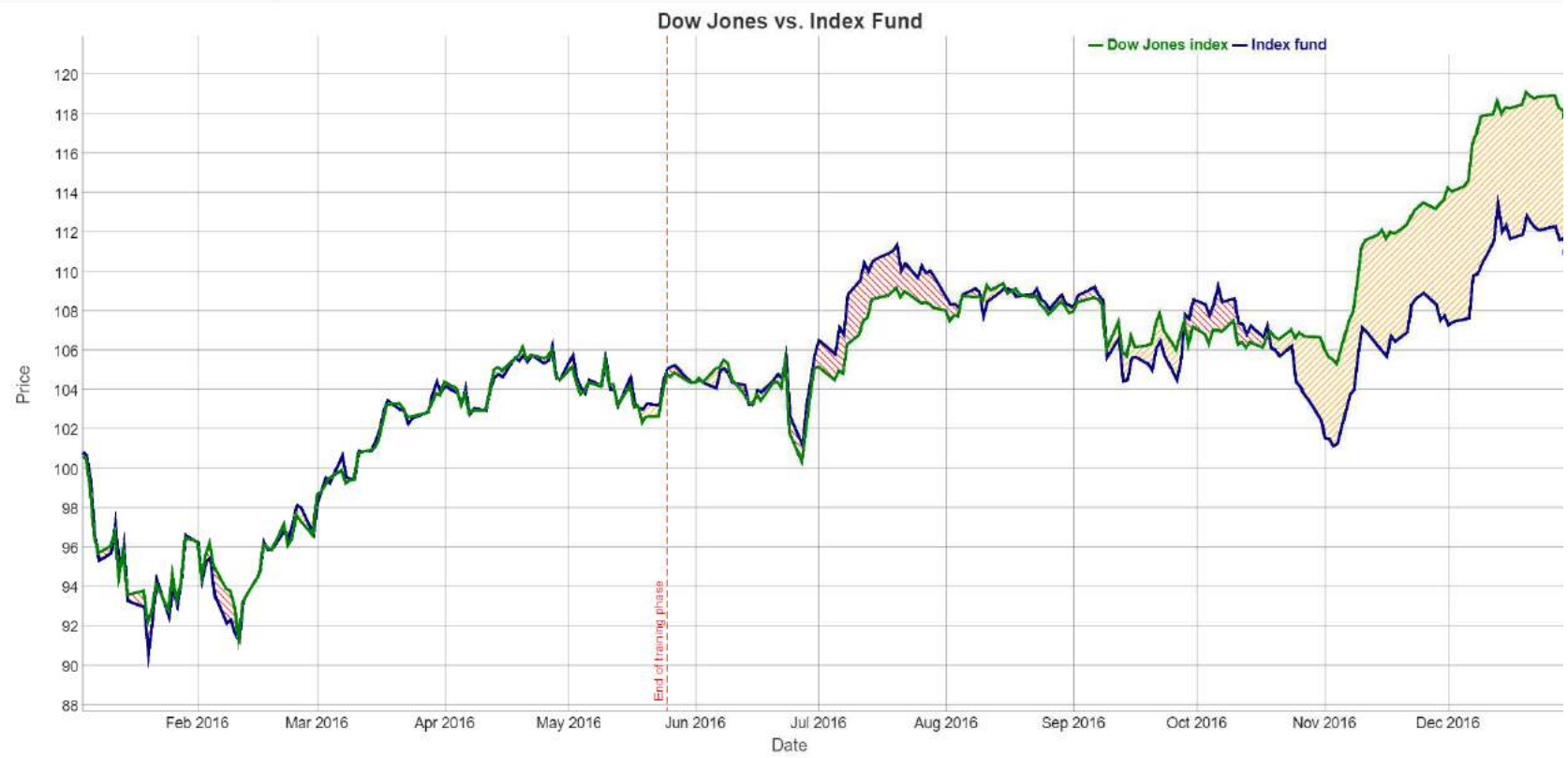
$$w_s \ge 0, \qquad p_s \in \{0,1\} \qquad (\forall s)$$

$$\text{slpos}_d \ge 0, \qquad \text{slneg}_d \ge 0 \qquad (\forall d)$$

Model: *Pickstock*

$$\text{minimize} \qquad \text{obj} := \sum_{ds} \text{slpos}_{ds} + \text{slneg}_{ds}$$

Model: *Pickstock*

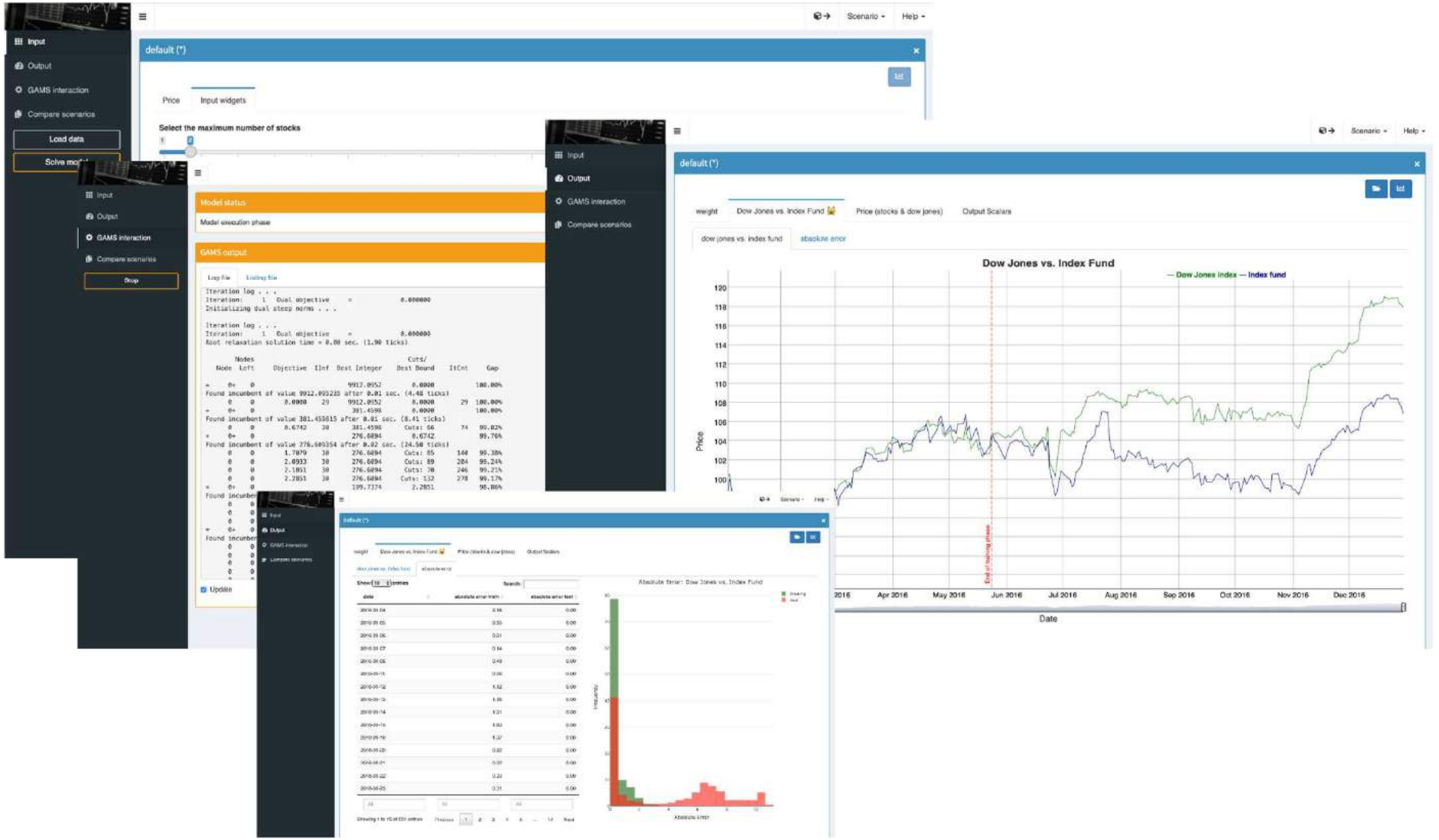


$$\text{minimize} \qquad \text{obj} := \sum_{ds} \text{slpos}_{ds} + \text{slneg}_{ds}$$

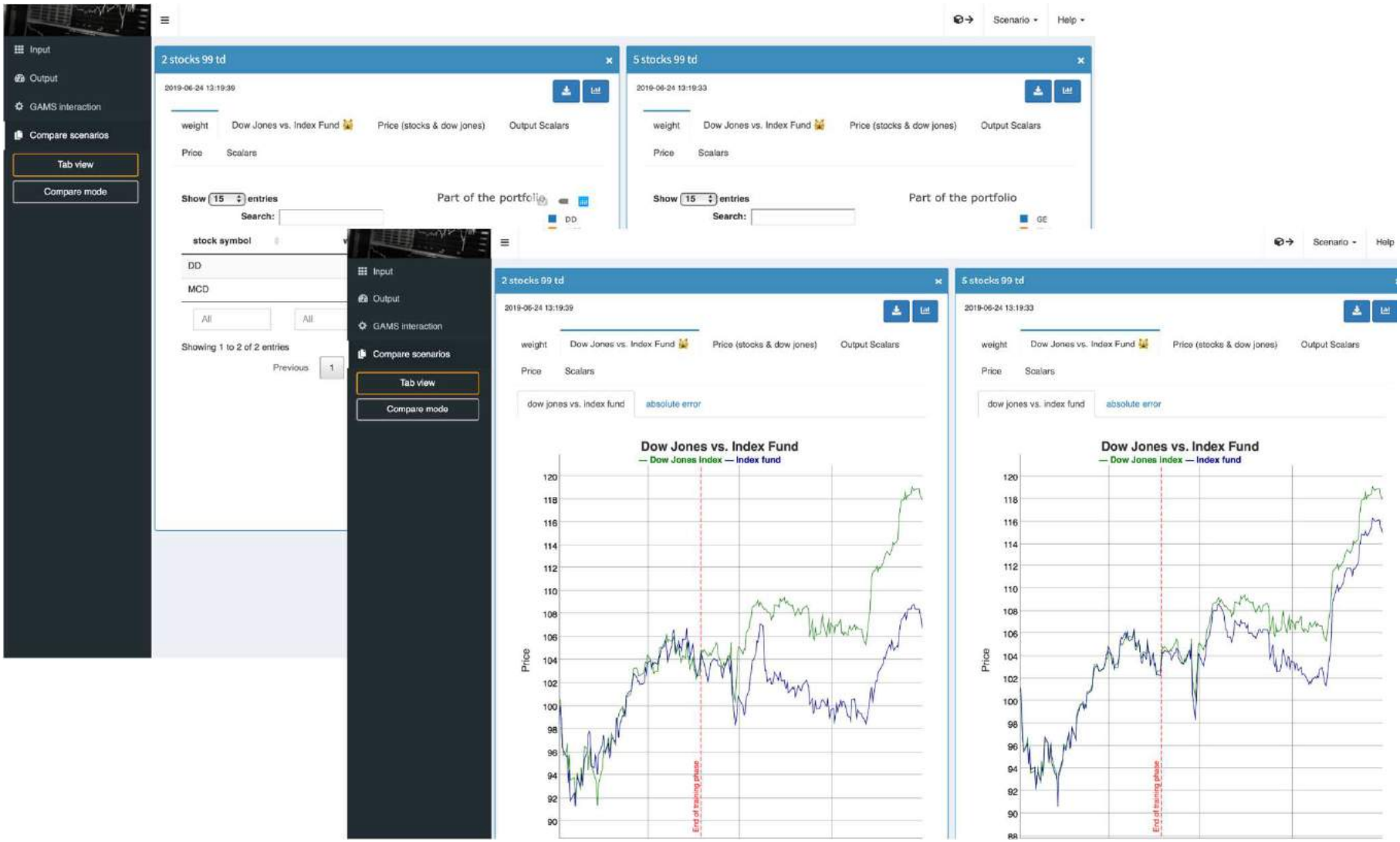
Demo:
Run

Look at an app built with MIRO

Run the model



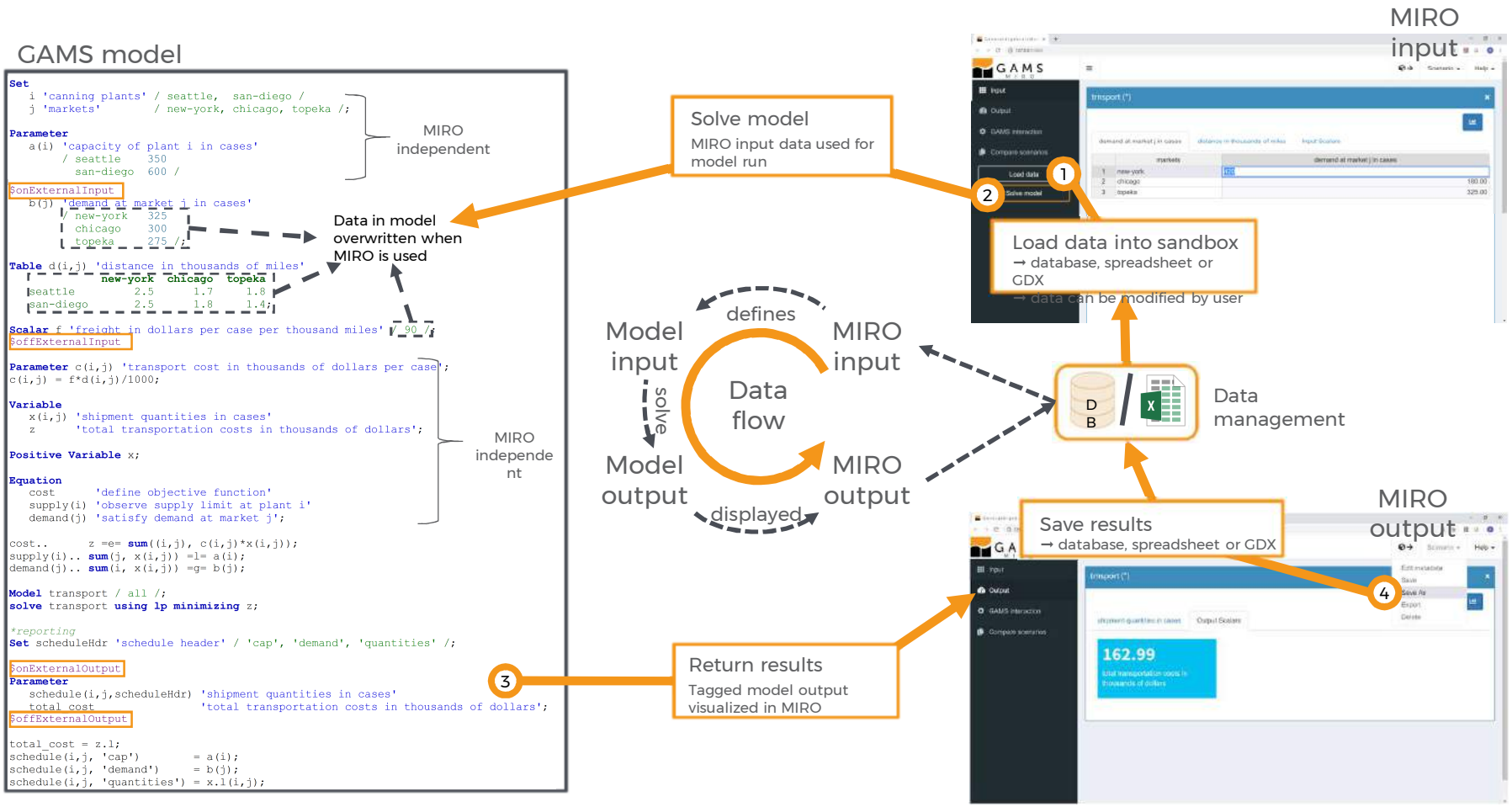
Compare scenarios



Demo:
How-to

Step by step:
Deployment of a GAMS model with GAMS MIRO

GAMS MIRO || DATA CONCEPT



Data exchange between GAMS model and MIRO

1. Data is loaded into the MIRO interface. These come either from the internal database or from external data sources such as Excel or GDX, but NOT directly from the GAMS model.
2. When clicking on solve, the data visible in the MIRO input section is sent to the GAMS model. All data of affected symbols in the model will be overwritten. Symbols that are not visible in MIRO are not touched.
3. The model is now run with the updated data. Afterwards the results are sent to MIRO and displayed in the output section.
4. From there, data can be saved in the internal database and/or exported as a file.

Scenario runs

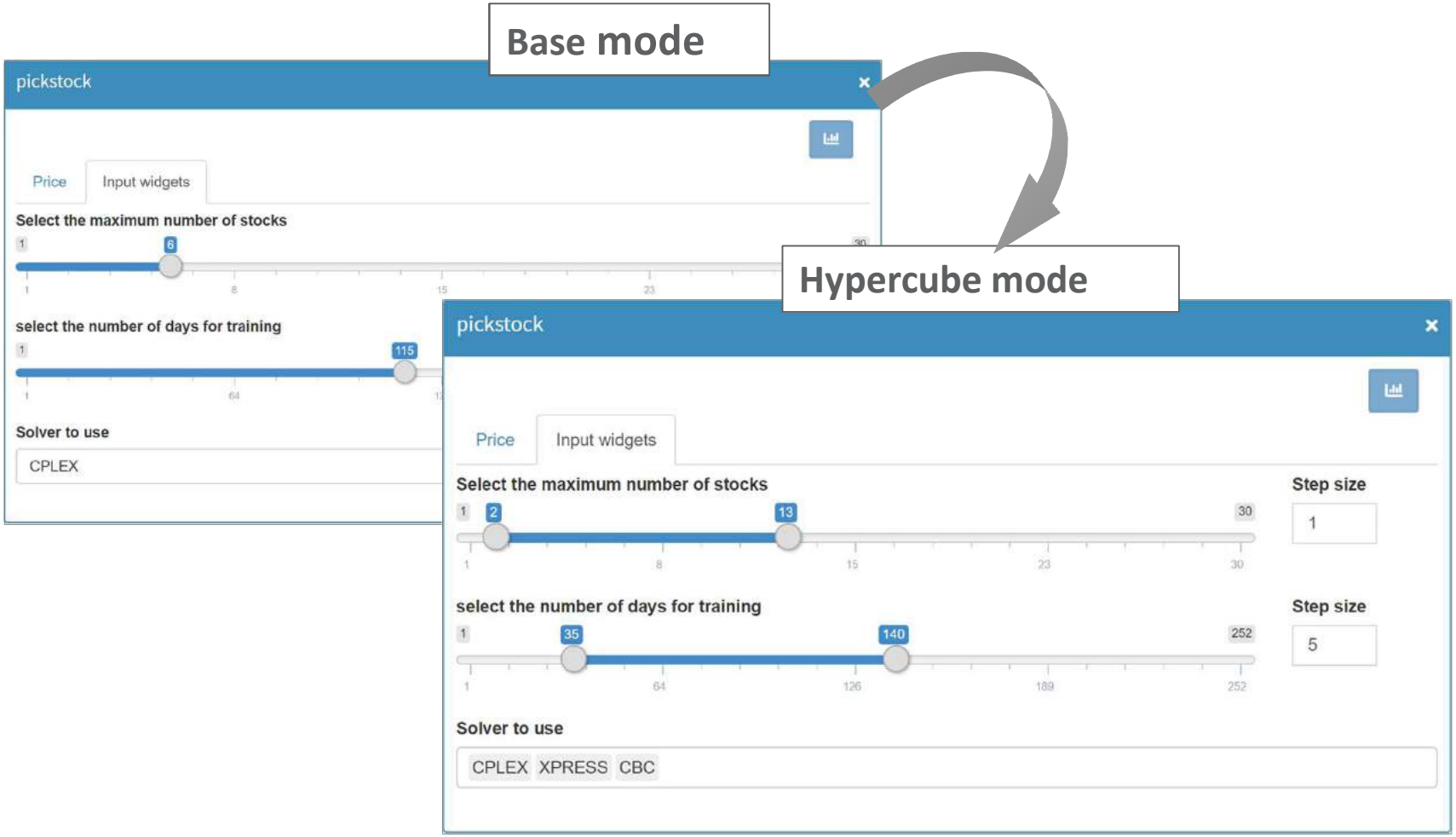
The GAMS MIRO Hypercube mode

Hypercube mode

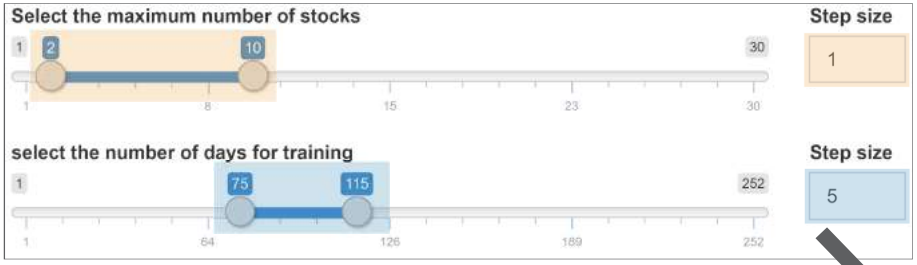
- Generate and analyze multiple scenarios in batch mode
- Goals:
  - Little to no effort to create interface
  - Generate only scenarios that have not yet been solved
  - Scenario management should be organized as clearly as possible
    - E.g. apply sophisticated filters to see only scenarios fulfilling certain criteria
  - Perform analyses related to KPIs and/or other indicators

Hypercube mode

scenario generation



Hypercube mode
scenario generation



+ 1

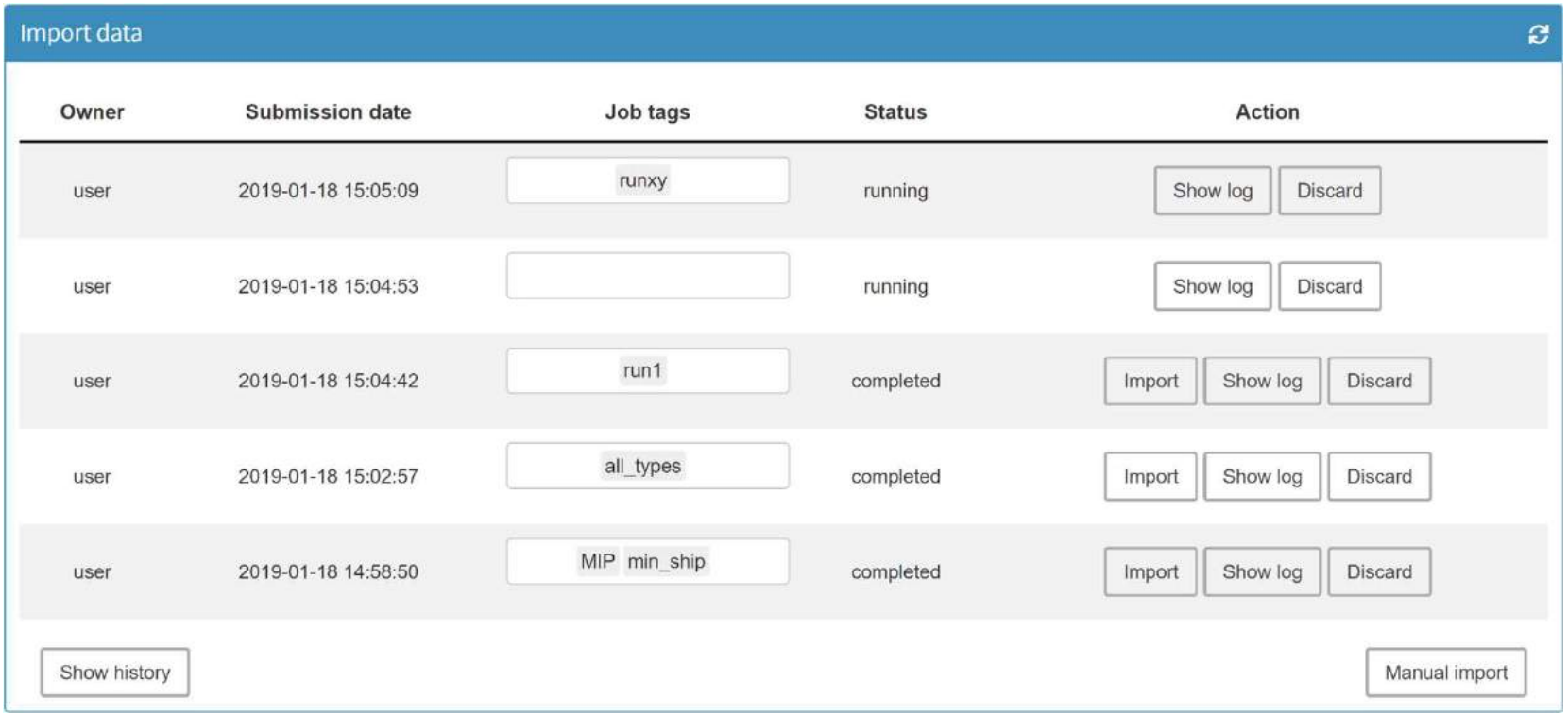
	2	3	4	5	6	7	8	9	10
75	1	2	3	4	5	6	7	8	9
80	10	11		13	14	15	16	17	18
85	19	20					25	26	27
90	28	2						5	36
95	37							44	45
100	46							53	54
105	55	56	57					62	63
110	64	65	66	67	68	69		71	72
115	73	74	75	76	77	78	79	80	81

+ 5

Number of scenarios
=
Cartesian product of scalar input combinations

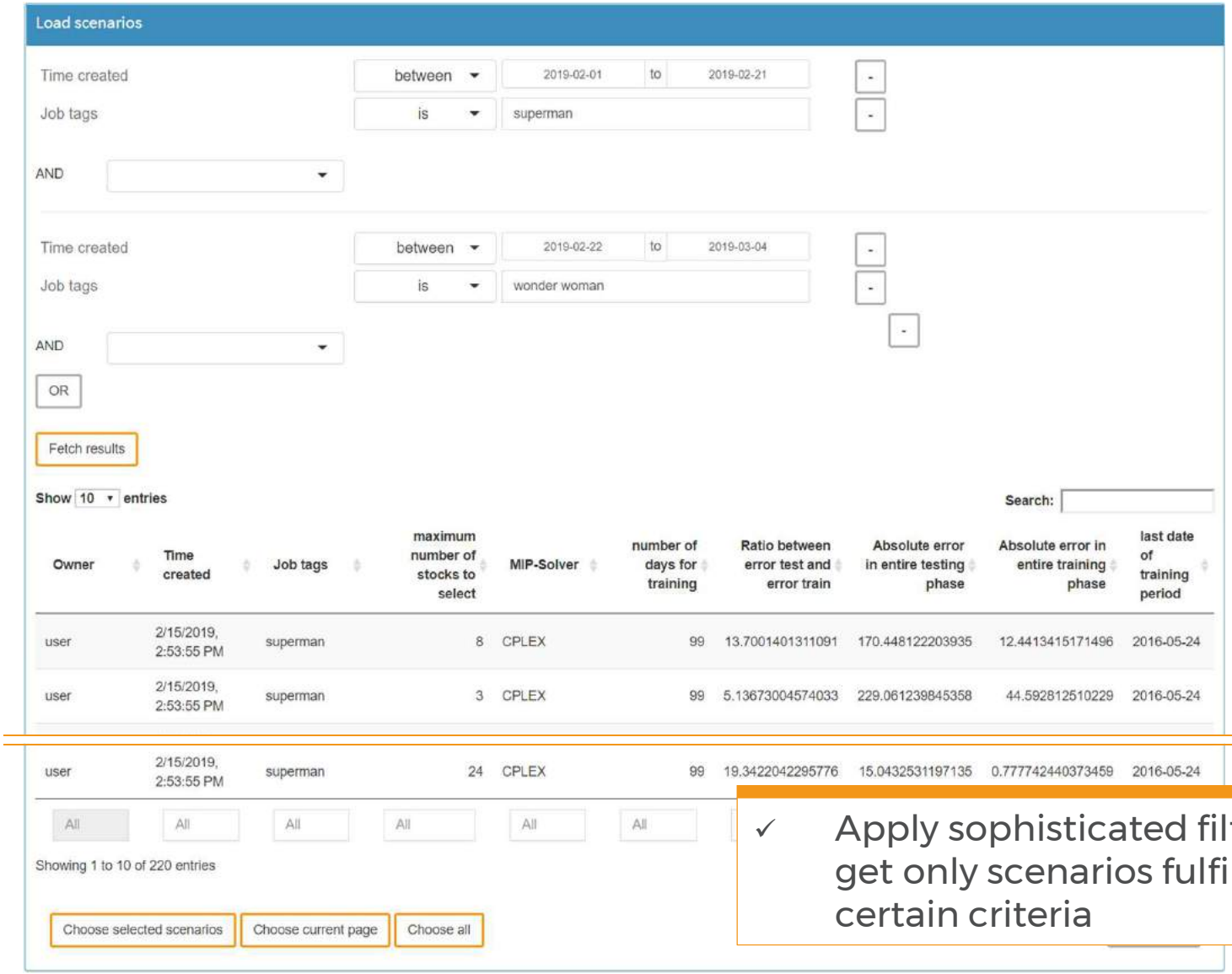
Hypercube mode

Data import & monitoring of scenario runs



Hypercube mode

Scenario management



✓ Apply sophisticated filters to get only scenarios fulfilling certain criteria

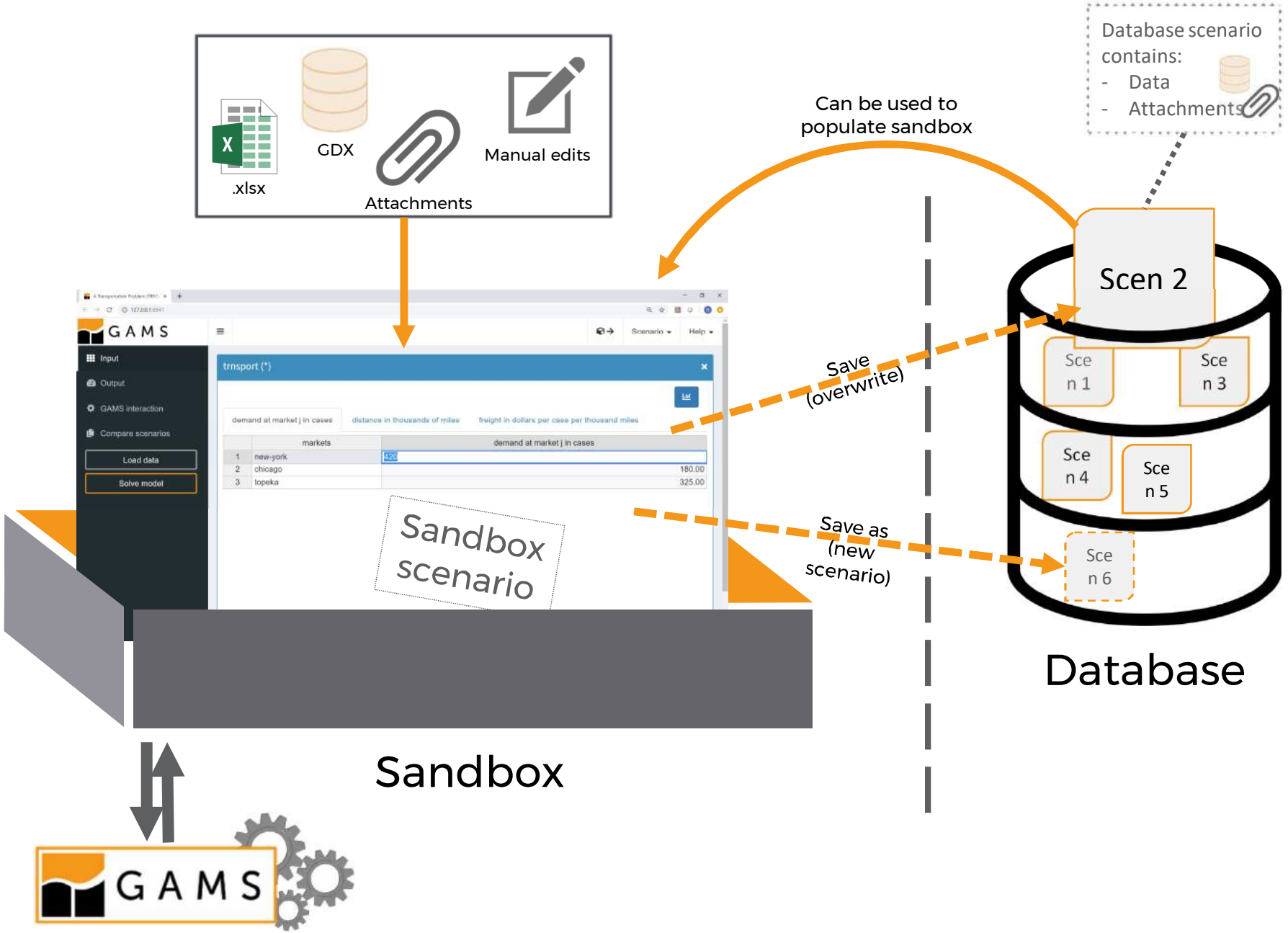
Hypercube mode

Analysis

✓ Perform analyses related to KPIs and/or other indicators

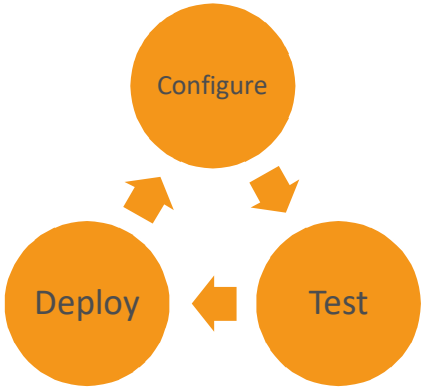
Demo

Hypercube mode


.xlsx
GDX
Attachments
Manual edits
Database scenario contains:
- Data
- Attachments
Can be used to populate sandbox
Scen 2
Sce n 1
Sce n 3
Sce n 4
Sce n 5
Sce n 6
Save (overwrite)
Save as (new scenario)
Database
GAMS
Input
Output
GAMS interaction
Compare scenarios
Load data
Solve model
trnsport (*)
demand at market j in cases
distance in thousands of miles
freight in dollars per case per thousand miles
markets
demand at market j in cases
1 new-york 325
2 chicago 180.00
3 topeka 325.00
Sandbox scenario
Sandbox
GAMS

Summary

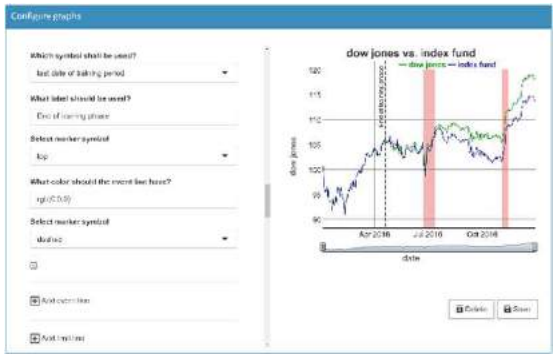
Summary

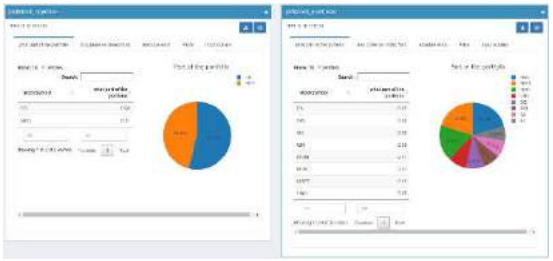


- Separation of tasks:
  - Modeling work
  - Model deployment

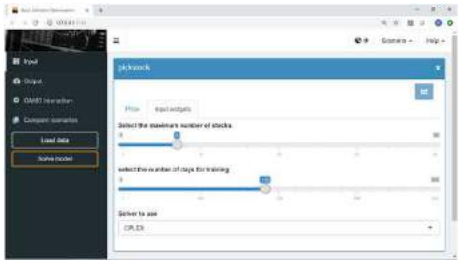
  → In OR projects often over several iterations

  → model deployment should not take much time (at least during these iterations)
- End-users are very often not modeling experts
- Quick & automated deployment of GAMS models
- Data visualization with charts / graphics
- Easy to configure
- Intuitive and structured work without GAMS knowledge
- Easy and convenient data and scenario management

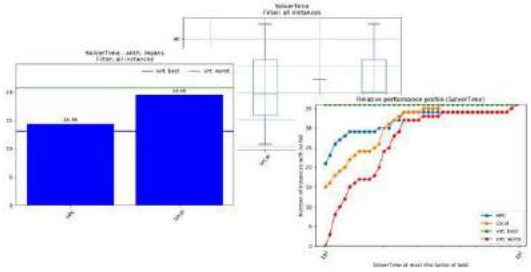


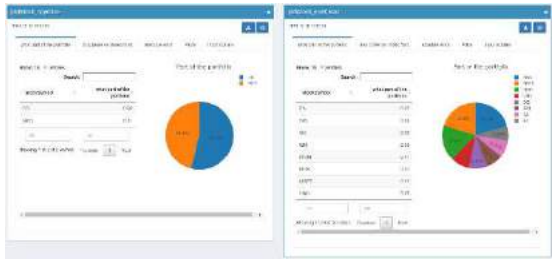


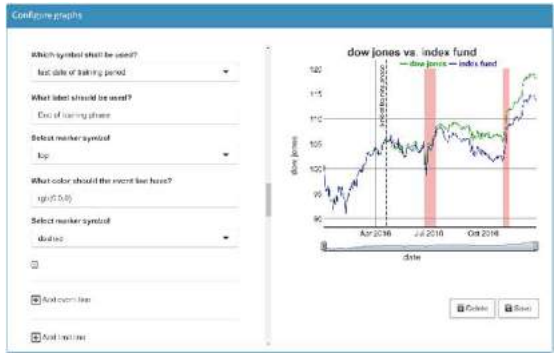
Summary



- Quick & automated deployment of GAMS models
- Data visualization with powerful charts / graphics
- Configuration mode
- Generation, processing and evaluation of scenario data
- Generation of performance statistics and sensitivity analyses
- Data export for external GAMS jobs and analyses
- Intuitive and structured work without GAMS knowledge
- Easy and convenient data and scenario management





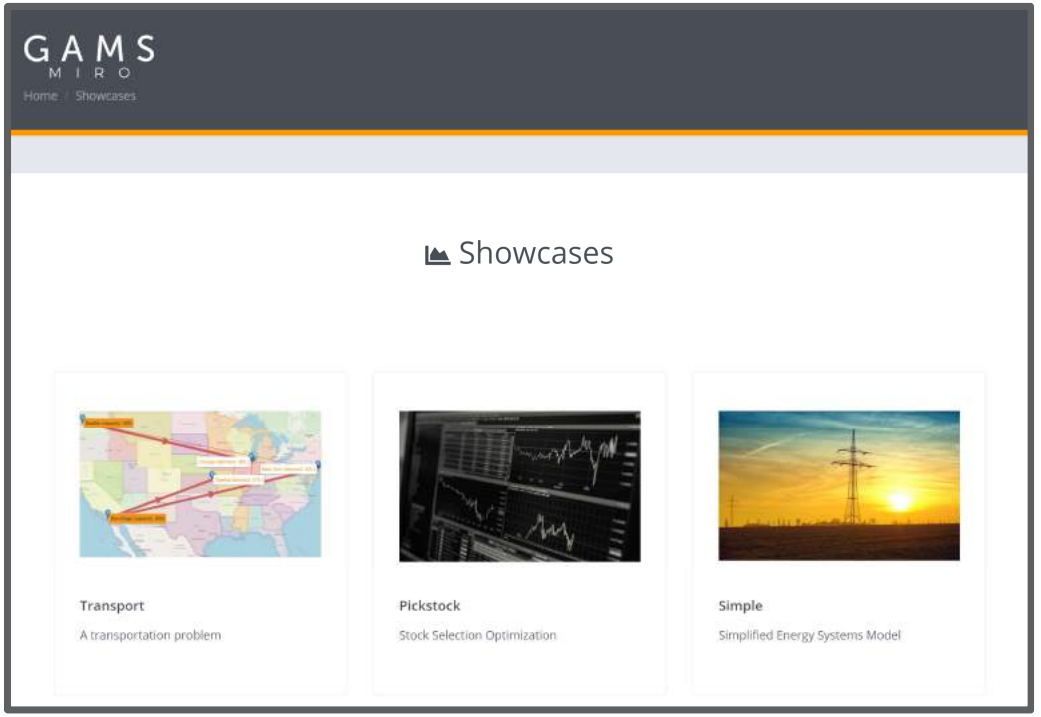


Outlook

MIRO 1.0

Outlook
MIRO 1.0

- Showcases

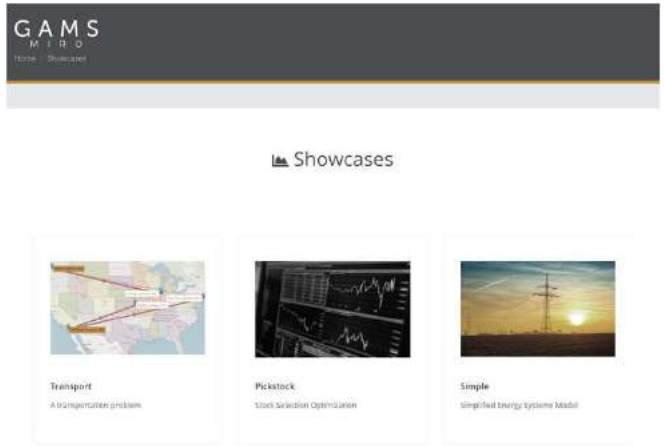


Already online!
https://www.gams.com/miro/index.html

You want to share your own MIRO app with others?
In order to show you the different application possibilities of MIRO, we want to expand our gallery with MIRO showcase apps permanently. If you have configured a MIRO app and would like to share it with others, you are welcome to do so here! Contact miro@gams.com if you want to share your app with us.

Outlook
MIRO 1.0

- Showcases
- Data validation – MIRO log



GAMS output

Log file | Listing file | MIRO log file

```
------------------------------------
        Executing transport
------------------------------------
a:: Capacity insufficient to meet demand
```

capacity of plant i in cases | demand at market j in cases

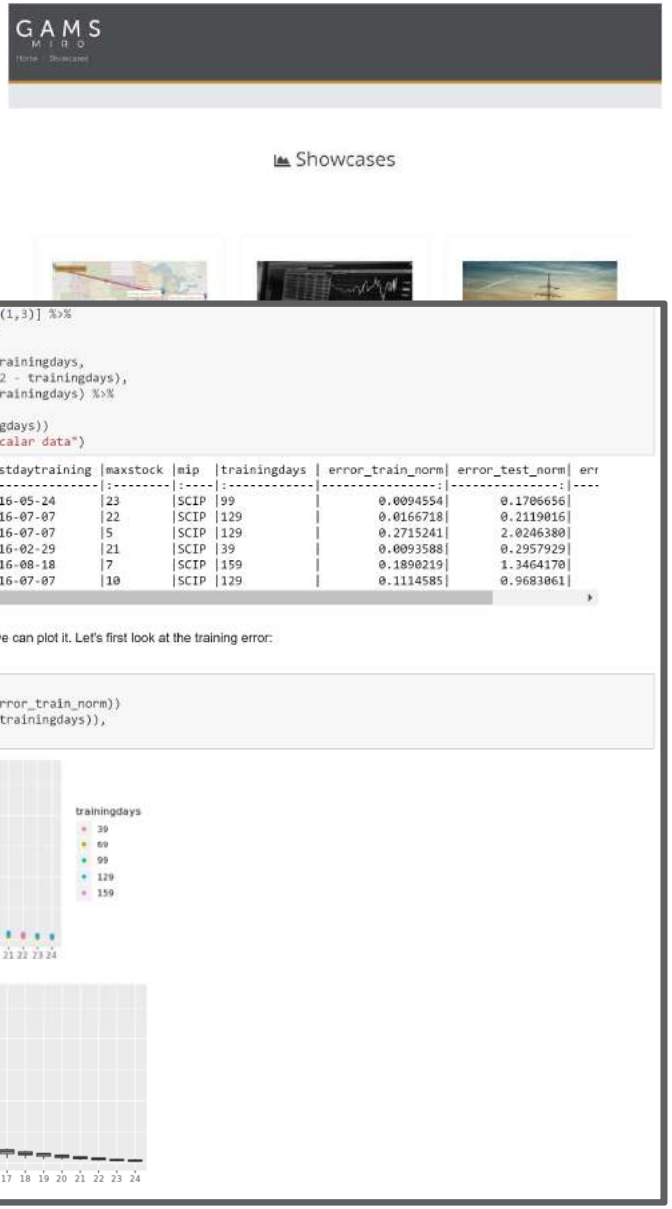
Market location information | Input widgets

- **Capacity insufficient to meet demand**

	canning plants	capacity of plant i in cases
1	Seattle	200.00
2	San-Diego	600.00

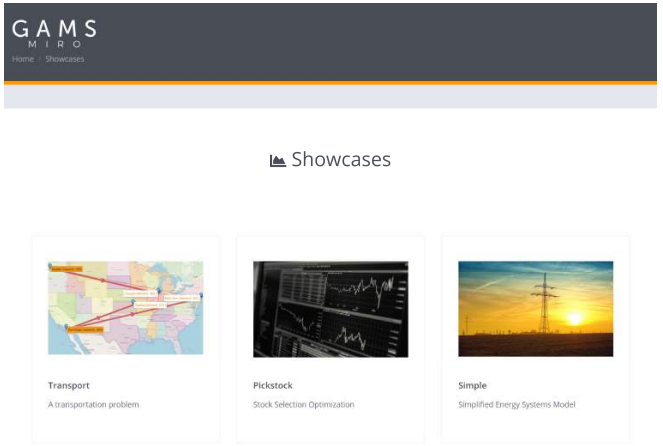
Outlook
MIRO 1.0

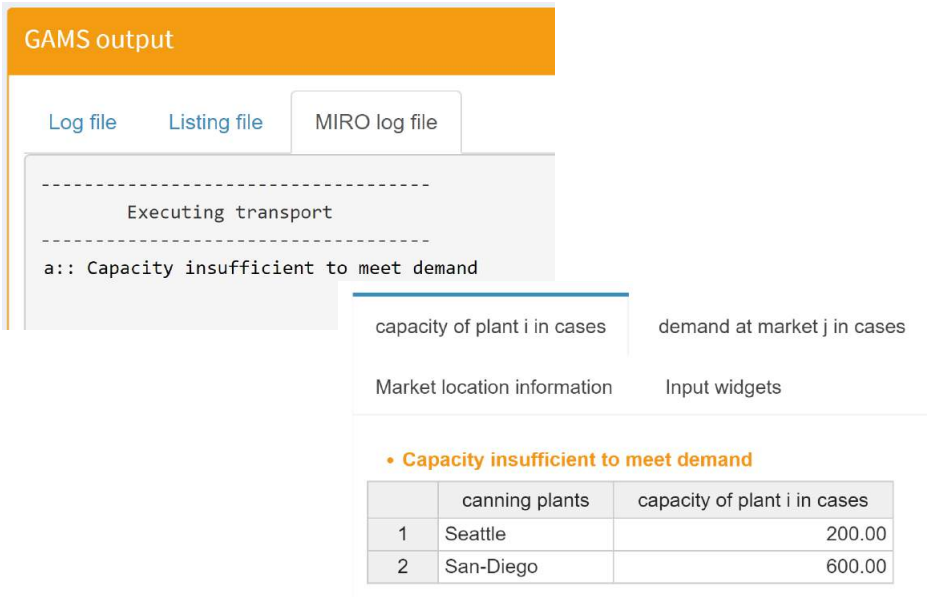
- Showcases
- Data validation – MIRO log
- Custom output for more detailed analyses (e.g. Jupyter notebooks)

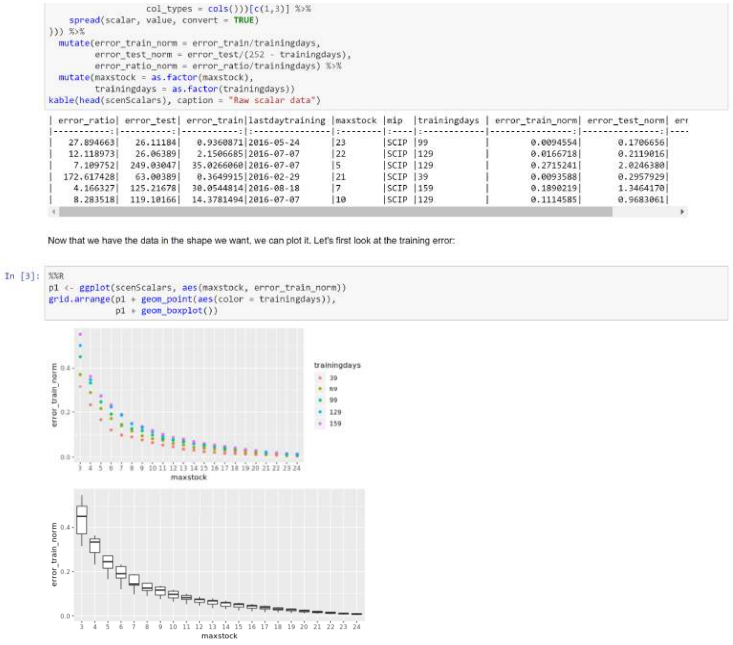


Outlook
MIRO 1.0

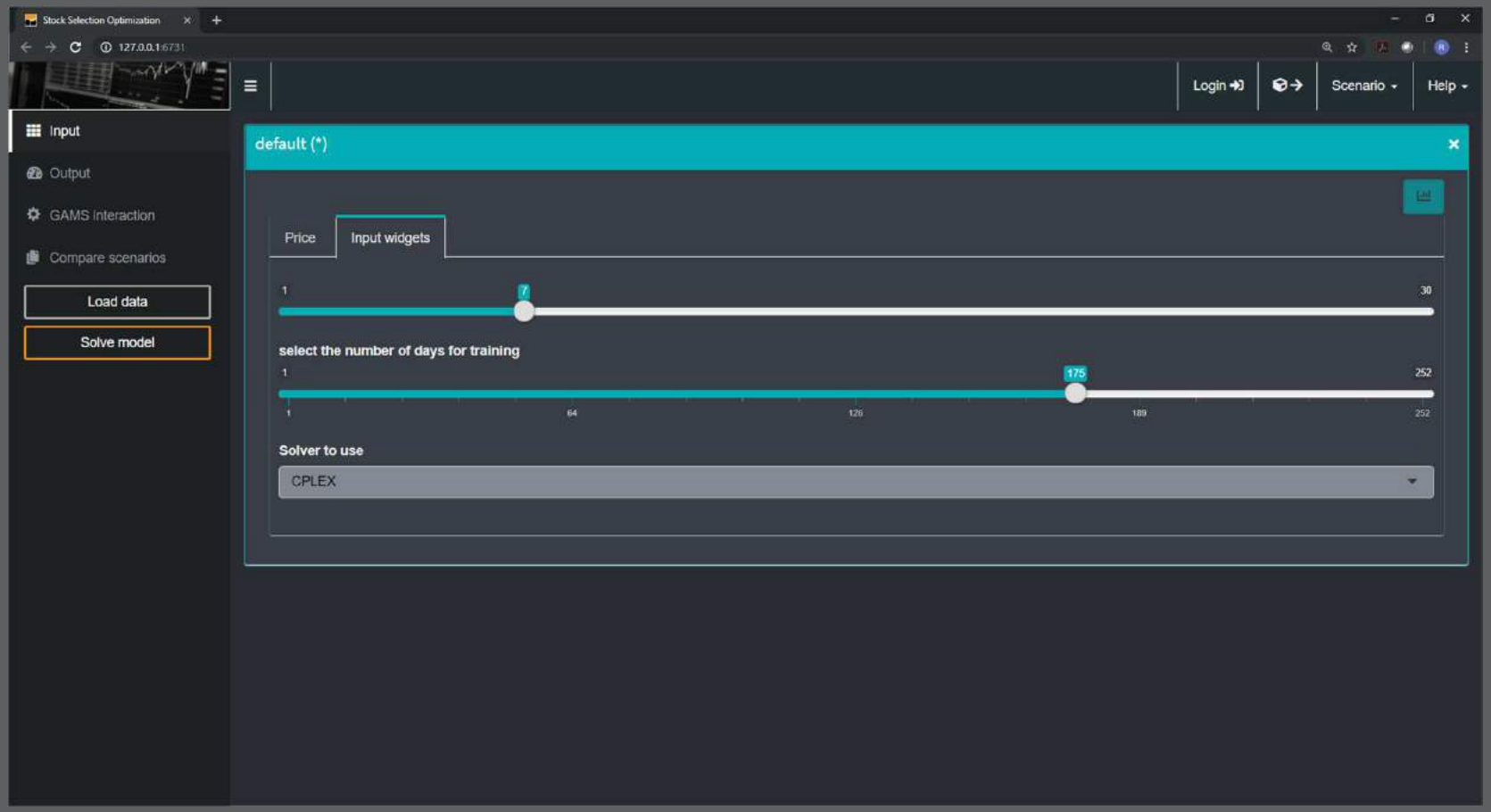
- Showcases
- Data validation – MIRO log
- Custom output for more detailed analyses (e.g. Jupyter notebooks)
- Graphs as data input







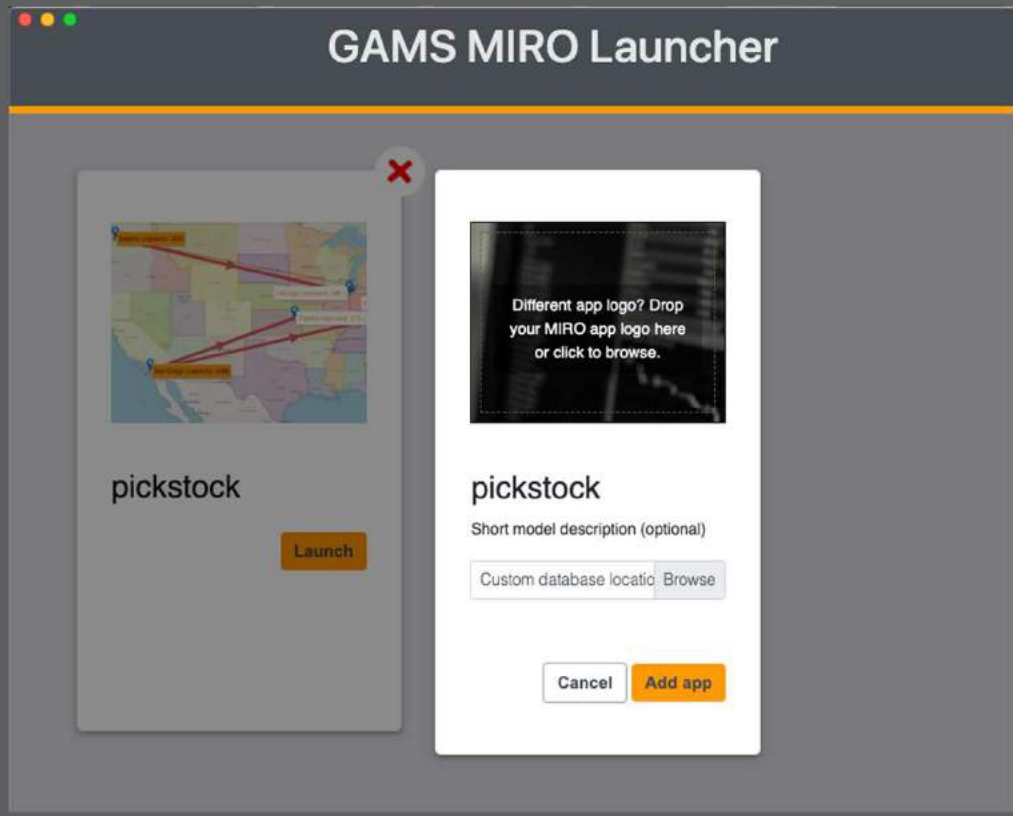
Outlook
MIRO 1.0



Outlook
MIRO 1.0

Deployment

- Select “Deploy App” from GAMS Studio
  - → Creates a MIRO App
- Add one or many of these Apps and add them to the MIRO Launcher
- Launcher allows to start App in browser or stand alone



Outlook
MIRO 1.0

Various other improvements done already:

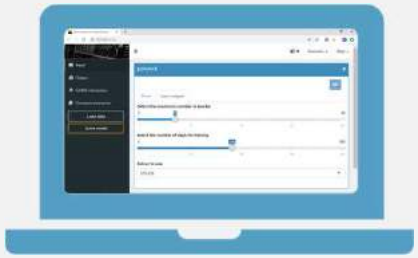
- Full Chinese language support
- Input/output symbols
- Heatmaps for input tables
- “Stop" with soft kill first, then hard kill
- Number of tabs visible can be configured (rest available via dropdown)
- Scenario comparison:
  - Input/output symbol tabs in different colors
  - Sandbox scenarios can be loaded directly
- Configuration mode restructured
- …

Outlook: MIRO on a server

Enterprise features

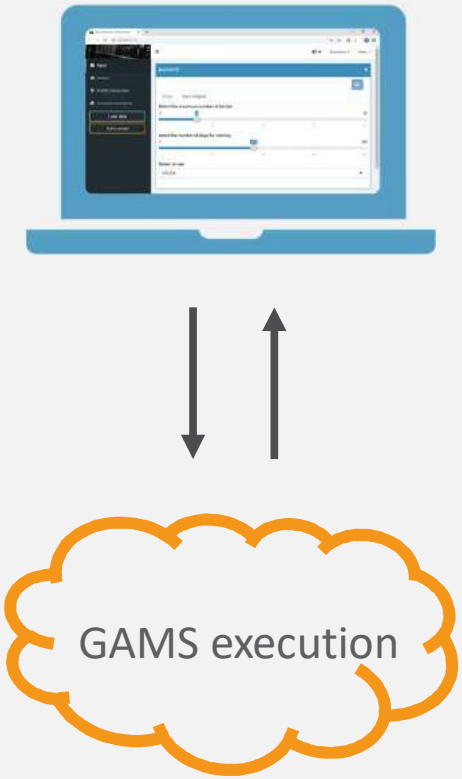
MIRO – job execution

Everything local

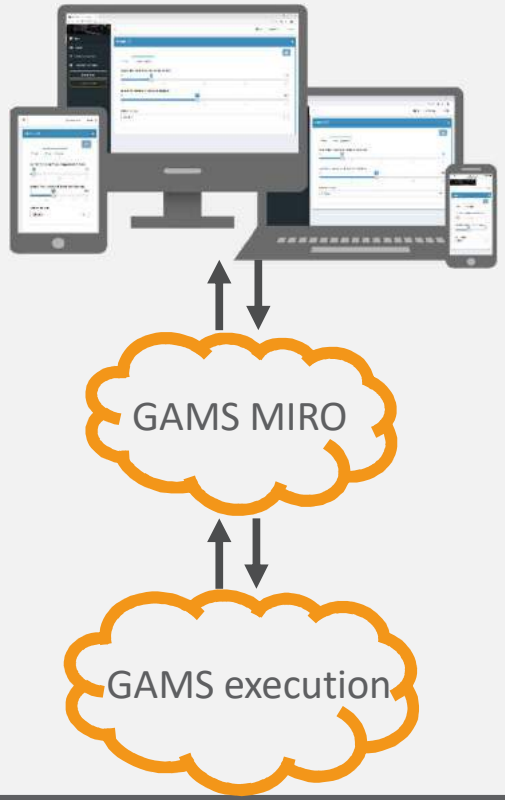


- GAMS installed
- MIRO installed
- Synchronous execution of GAMS jobs

Local MIRO application – remote GAMS execution



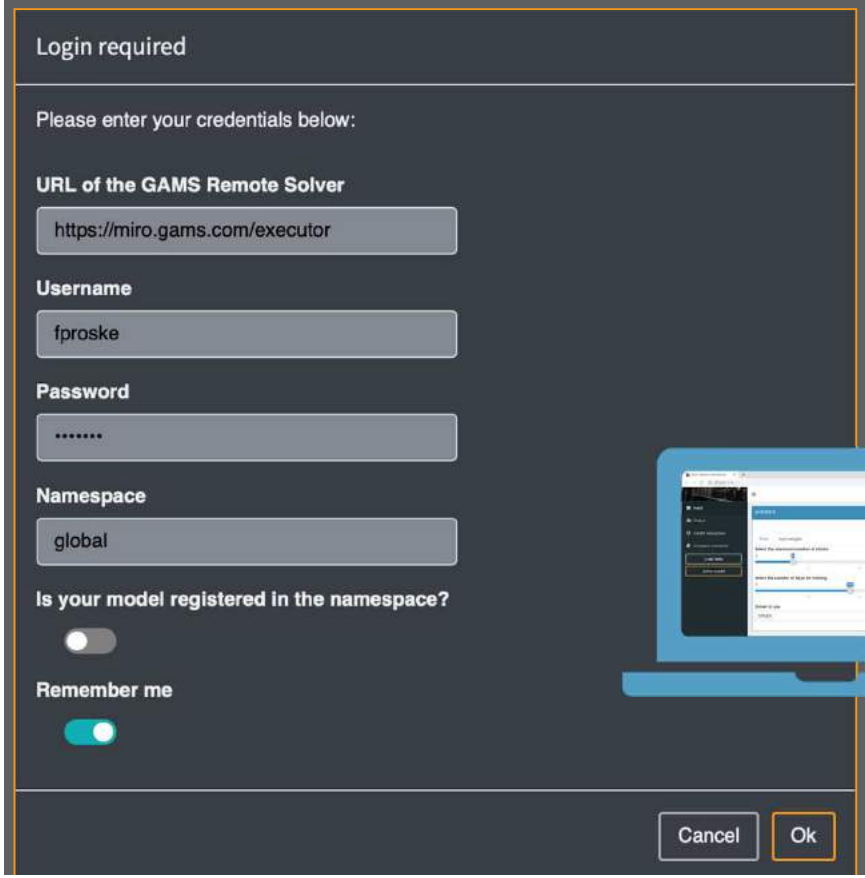
Everything on a server



Local MIRO – remote GAMS execution

- Only MIRO installed locally
- Computation on server
- Asynchronous execution of jobs

Security
- ✓ Authentication (for remote execution) handled by MIRO
- ✓ TLS enforced
- ✓ Certificate pinning
- ✓ Token instead of user password stored

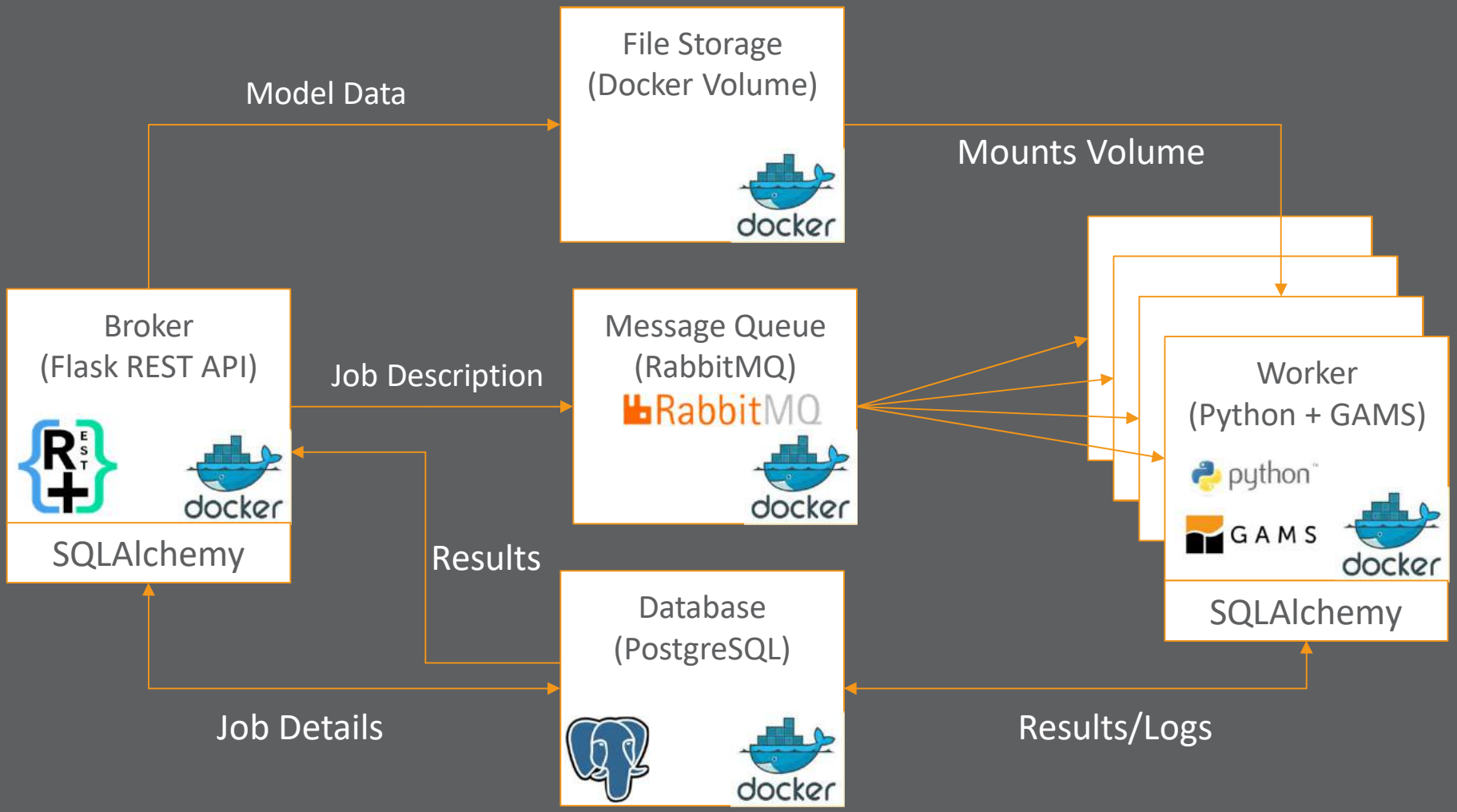


Everything on a server

- Neither GAMS nor MIRO installation necessary
- Can be hosted by GAMS or on customer's server(s)

Security
- Authentication via LDAP, Keycloak, Kerberos, OpenID Connect, etc.
- Remote executor authentication disabled

Docker network



QUESTIONS?

Or: What do you miss?

GAMS

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