
Cloud Services for Optimization Modeling Software

Robert Fourer

AMPL Optimization Inc.

`4er@ampl.com`

APMOD 2016: Applied Mathematical Programming and Modelling

Brno, Czech Republic

Session 2A — Wednesday, 8 June 2016 — 10:50-12:00

Abstract

Optimization modeling systems first became available online soon after the establishment of the NEOS Server almost 20 years ago. This presentation describes the evolution of NEOS and other options in what came to be known as cloud computing, with emphasis on the modeling aspects of optimization. In comparison to solver services that compute and return optimal solutions, cloud services for building optimization models and reporting results have proved especially challenging to design and deliver. A collaboration between local clients and cloud servers may turn out to provide the best environment for model development.

Cloud Services / Software as a Service

Client side

- Computing device owned by the user's organization
- Application running interactively on a local processor

Server side

- Workstation owned by a computing provider
- Service running automatically on a remote processor

Not considered here . . .

- User logged in to the remote computer
- Server side owned by the user's organization

Optimization

No one way to optimize

- Numerous problem classes
- Alternative methods for each class
- Competing free and commercial *solvers*

Models built to order

- Competing *modeling systems*
- Each system supports multiple solvers
- Many solvers work with multiple systems

A tangle of software

- Market not dominated by comprehensive packages
 - * compare statistics, simulation
- Performance varies greatly

Optimization as a Service

NEOS Server

- Free cloud service for optimization since 1996
- Originated many ideas still relevant today

Gurobi Instant Cloud

- Commercial cloud service for optimization
- Most extensive recent cloud offering

... both offer modeling language interfaces

NEOS Server www.neos-server.org

Network Enabled Optimization System

- Originated 1995 at Argonne National Laboratory
 - * U.S. Department of Energy
- Since 2011 at Wisconsin Institutes for Discovery
 - * University of Wisconsin, Madison

Free access to optimization software

- Over 40 solvers
- Optimization modeling languages

Origins

Meeting over lunch in spring 1995

- Argonne representatives (?)
 - * Rick Stevens, Jorge Moré, Steven Wright
- Northwestern representatives (?)
 - * Jorge Nocedal, Bob Fourer

Plan for a new project

- Automate the use of optimization libraries
- Promote “optimization as an internet resource”
- Take advantage of the “new” World Wide Web

Architecture

Distributed workstations

- Offer various interfaces & solvers
- Process submissions on demand
- Use *Wisconsin HTCondor pools* and other facilities

Central scheduler

- Receives and queues submissions
- Sends submissions to appropriate workstations
- Returns results

Minimal hands-on management

- *Distributed*: Install NEOS software on workstations
- *Central*: Update server database of workstation locations and abilities

NEOS Server

Original Facilities

Local submission clients

- Email
- Website
- NEOS submission tool

Problem description formats

- Linear: MPS and other solver files
- Nonlinear: Fortran or C programs
 - * automatic differentiation for use by solvers

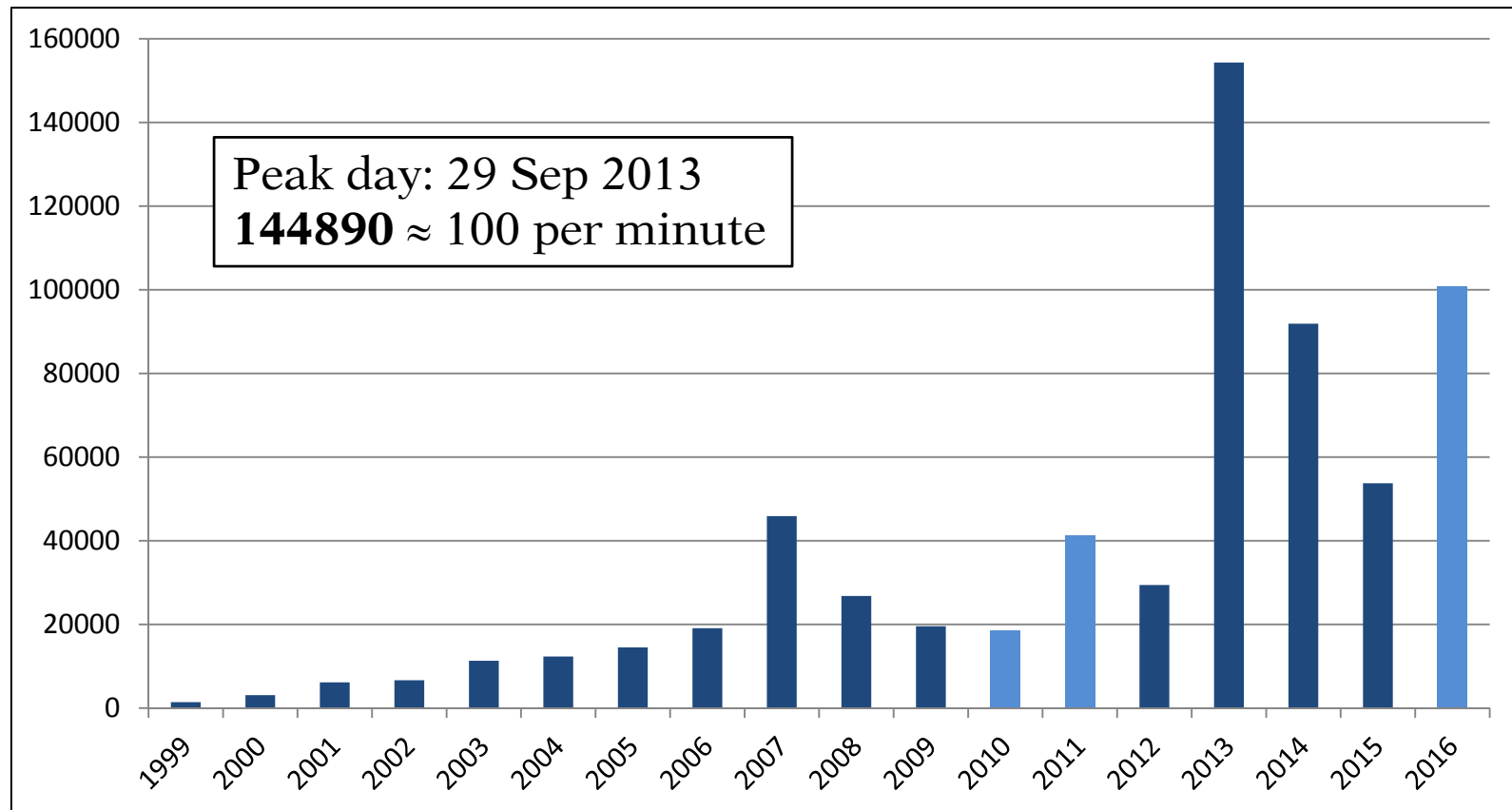
W. Gropp and J.J. Moré, 1997. **Optimization Environments and the NEOS Server**. *Approximation Theory and Optimization*, M. D. Buhmann and A. Iserles, eds., Cambridge University Press, 167-182.

J. Czyzyk, M.P. Mesnier and J.J. Moré, 1998. **The NEOS Server**. *IEEE Journal on Computational Science and Engineering* **5**(3), 68-75.

NEOS Server

Impact: Total Submissions

Monthly rates since 1999

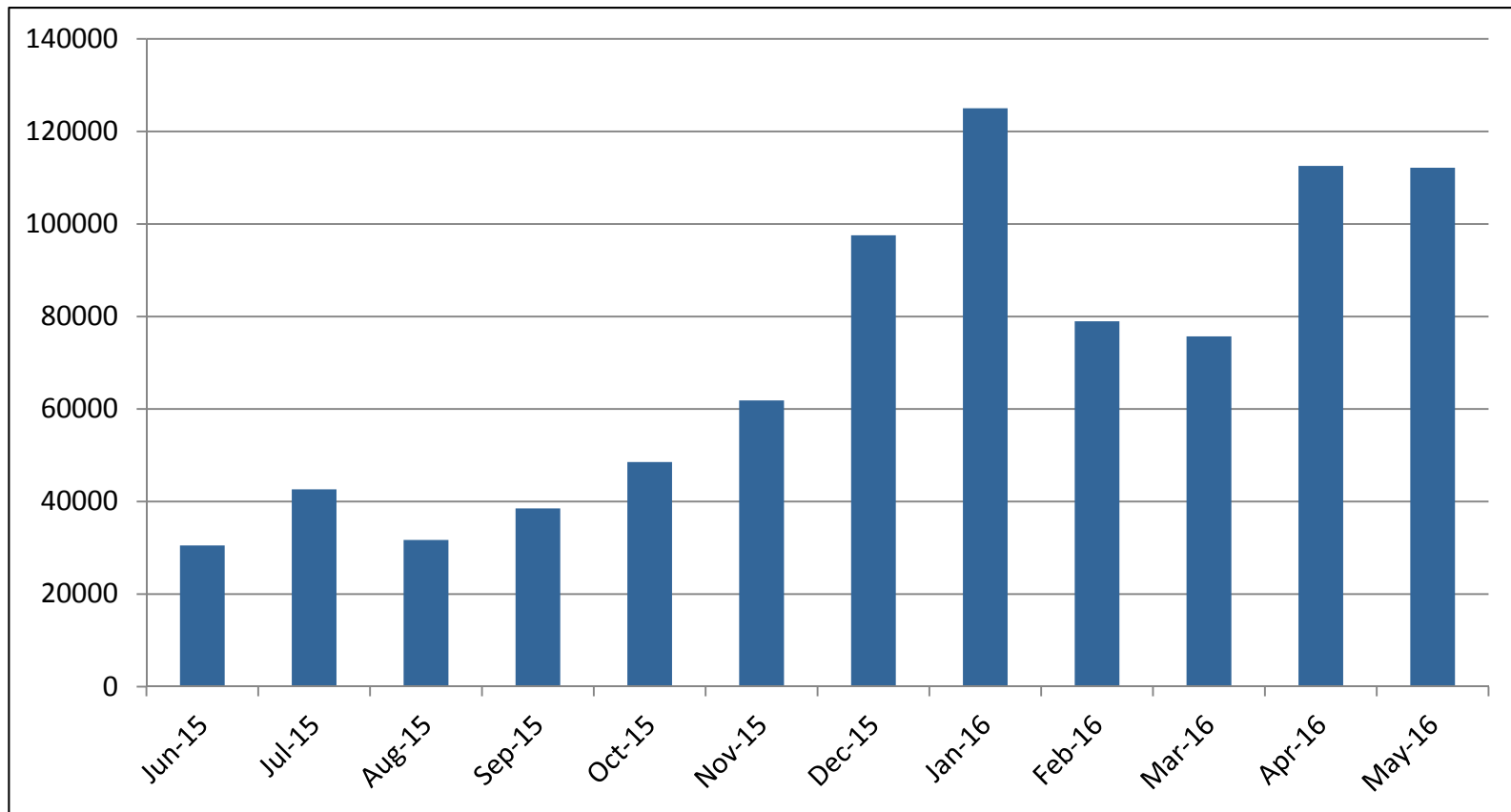


45000/month \approx one per minute

NEOS Server

Impact: Recent Submissions

Monthly rates for past year



45000/month \approx one per minute

Assessment

Strengths

- Free
- Choice of solvers
 - * Every popular solver available
- Easy to use
 - * No account setup
 - * No advance scheduling

Weaknesses

- Stand-alone design
- Non-profit management
 - * Limited support & development
 - * No guarantee of confidentiality
 - * No guarantee of performance

Modeling Languages in NEOS

Modeling language inputs

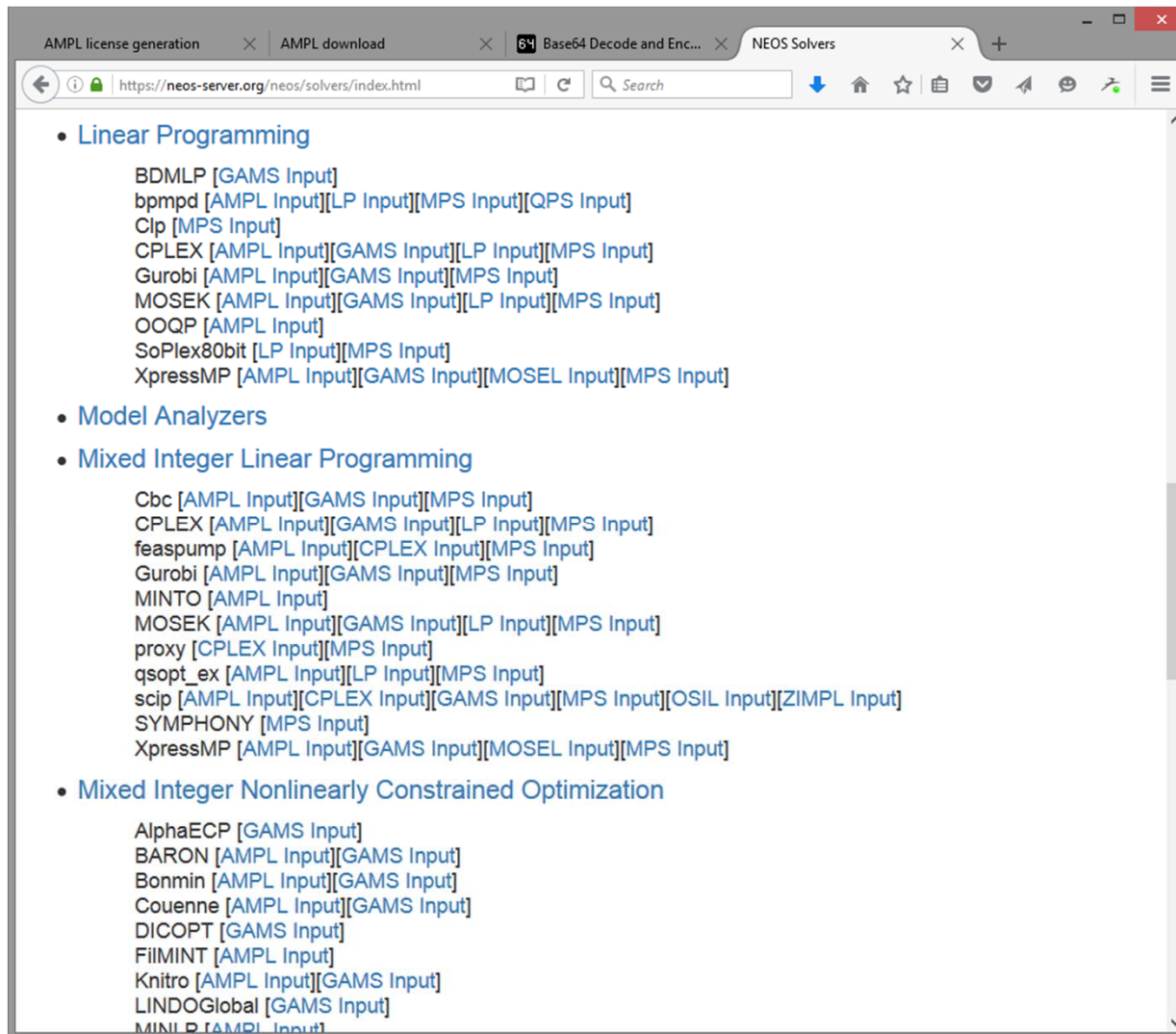
- AMPL model, data, commands files
- GAMS model, options,.gdx files

Modeling language operation

- User chooses a solver and a language
- NEOS scheduler finds a compatible workstation
- NEOS workstation invokes modeling language system with given inputs
- Modeling language system invokes solver

E.D. Dolan, R. Fourer, J.J. Moré and T.S. Munson,
Optimization on the NEOS Server. *SIAM News* **35:6**
(July/August 2002) 4, 8–9. www.siam.org/pdf/news/457.pdf

Solver & Language Listing



NEOS Server

AMPL Input Page



The screenshot shows a web browser window with the URL <https://neos-server.org/neos/solv>. The browser's address bar shows the page title "NEOS Server: CPLEX". The page content includes a navigation bar with "NEOS", "Contact", and "Help" links, and "Sign In" and "Sign Up" buttons. A large banner features the "neos SOLVERS" logo and the word "Optimization" in a large, stylized font. A text box on the right side of the banner reads "NEOS Interfaces to CPLEX" and lists "WWW Form & Sample Submissions", "Email", and "XML-RPC" as options. Below the banner, the heading "CPLEX" is followed by text explaining that the NEOS Server offers the IBM ILOG CPLEX Optimizer for solving linear programming (LP) problems in AMPL format. It provides links for more information on IBM Decision Optimization products and the IBM Academic Initiative. The section "Using the NEOS Server with AMPL/CPLEX" explains that users must submit a model in AMPL format, including a model file, a data file, and a commands file. A note specifies that an email address is required for submissions and that the XML-RPC interface requires a specific line in the XML file.

NEOS SOLVERS

Optimization

NEOS Interfaces to CPLEX

WWW Form & Sample Submissions
Email
XML-RPC

CPLEX

The NEOS Server offers the IBM ILOG [CPLEX Optimizer](#) for the solution of linear programming (LP) problems that can be modeled in [AMPL](#) format.

For information on IBM Decision Optimization products, including the CPLEX Optimizer, visit [IBM Decision Optimization](#).

For information on all IBM software available to academics, visit the [IBM Academic Initiative](#).

Using the NEOS Server with AMPL/CPLEX

The user must submit a model in [AMPL](#) format to solve a linear program. The [examples section](#) of the AMPL website provides examples of models in AMPL format. The LP problem must be specified by a model file with the options of a data file and a commands file. If the commands file is specified, it must contain the AMPL solve command. However, the command file must *not* contain the `model` or `data` commands. The model and data files are renamed internally by NEOS.

Note: An email address is required for any submissions that use CPLEX. This email address will be forwarded to IBM and may be used by IBM for promotional purposes. If using the XML-RPC interface, you must add the line `<email>your.address@email.edu</email>` into the XML file that is sent to NEOS.

NEOS Server

AMPL Input Page

The screenshot shows a web browser window with the URL <https://neos-server.org/neos/solv>. The browser's address bar shows several tabs, including "NEOS Server: CPLEX". The page has a dark navigation bar with "NEOS", "Contact", and "Help" links, and "Sign In" and "Sign Up" buttons. The main content area contains three file selection sections and a comments box:

Enter the location of the AMPL model file (local file)
Model File:

Enter the location of the AMPL data file (local file)
Data File:

Enter the location of the AMPL commands file (local file)
Commands File:

Comments:

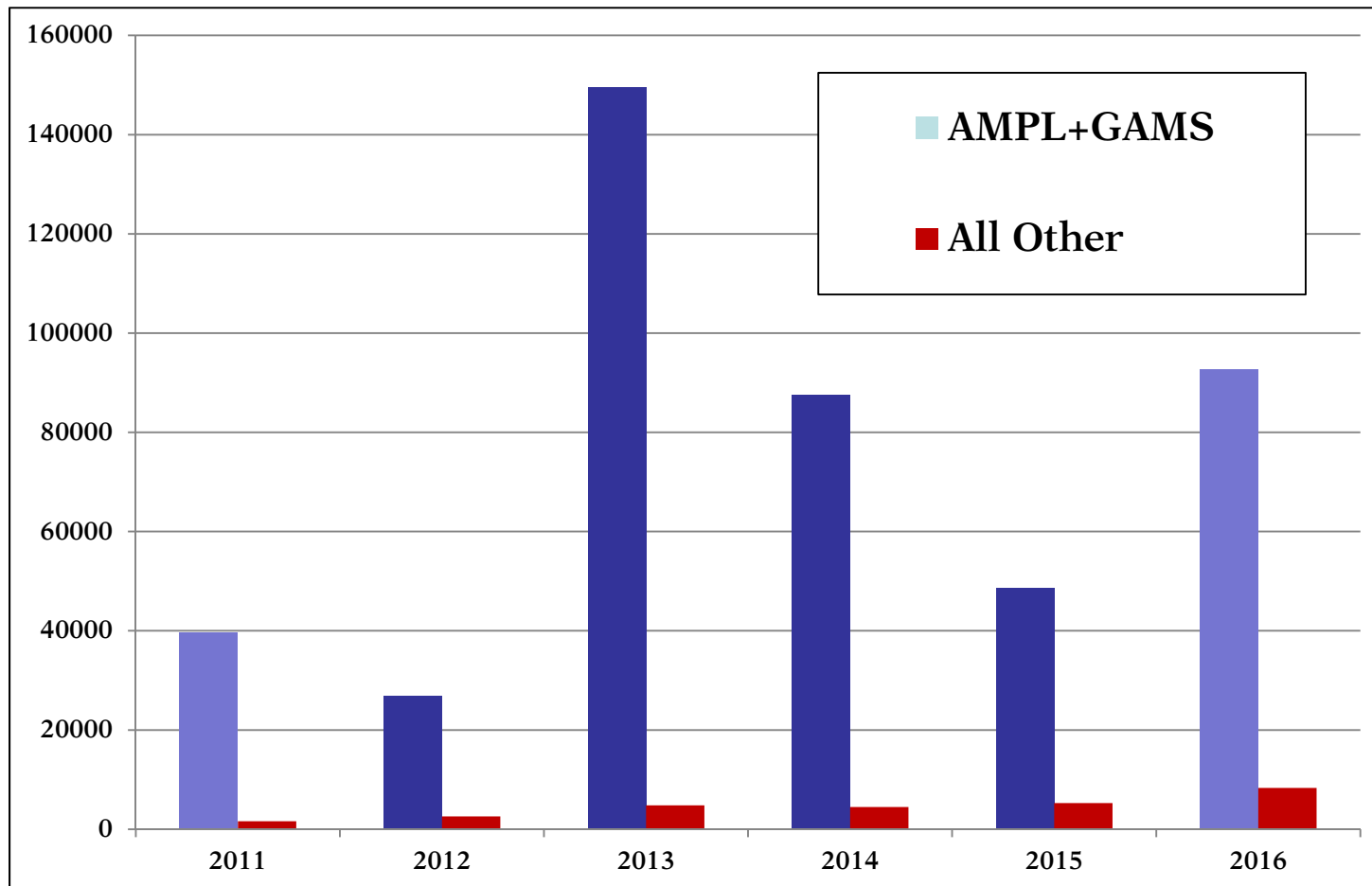
NEOS Server

AMPL Input Page

The screenshot shows a web browser window with the URL <https://neos-server.org/neos/solv>. The browser's address bar shows several tabs, including "NEOS Server: CPLEX". The page header includes "NEOS", "Contact", and "Help" links, along with "Sign In" and "Sign Up" buttons. Below the header is a "Comments:" section with a large text input area. Underneath the comments section are two checkboxes: "Dry run: generate job XML instead of submitting it to NEOS" and "Short Priority: submit to higher priority queue with maximum CPU time of 5 minutes". Below these checkboxes is an "e-mail address:" label and a text input field. A line of text states: "By submitting a job, you have accepted the [Terms of Use](#)". Below this text are two buttons: "Submit to NEOS" and "Clear this Form". A warning message reads: "Please do not click the 'Submit to NEOS' button more than once." At the bottom of the page, there is a footer with "Comments and Questions · [Terms of Use](#)", the logos for "WISCONSIN" and "WISCONSIN INSTITUTES FOR DISCOVERY", and a copyright notice: "Copyright © 2016, [Wisconsin Institutes for Discovery](#) at the University of Wisconsin, Madison · [Terms of Use](#)".

Impact: Modeling Languages

Monthly rates since 1999



NEOS Server

Assessment: Modeling Languages

Strengths

- Easy to get started using NEOS
- High-level representation supporting >20 solvers

Weaknesses

- Stand-alone design

NEOS Server

APIs

Application programming interfaces

- Access NEOS from a local program

Implementations

- Version 1: XML-RPC remote procedure call
- Version 5: full Python API

Uses

- NEOS submission tool
- Custom-built applications
- **NEOS as a “solver” for modeling environments**

NEOS Server

NEOS in Modeling Languages

New “solvers”

- Kestrel for AMPL
- Kestrel for GAMS

Familiar operation

- Choose Kestrel as the local “solver”
- Set an option to choose a real solver on NEOS
- Initiate a solve and wait for results

E.D. Dolan, R. Fourer, J.-P. Goux, T.S. Munson and J. Sarich,
**Kestrel: An Interface from Optimization Modeling Systems
to the NEOS Server.** *INFORMS Journal on Computing* **20**
(2008) 525–538. [dx.doi.org/10.1287/ijoc.1080.0264](https://doi.org/10.1287/ijoc.1080.0264)

AMPL Interactive Session

```
ampl: model sched1.mod;
ampl: data sched.dat;

ampl: let least_assign := 16;

ampl: option solver kestrel;
ampl: option kestrel_options 'solver=cplex';

ampl: solve;

Connecting to: neos-server.org:3332
Job 4679195 submitted to NEOS, password='JMNRQoTD'

Check the following URL for progress report :

http://neos-server.org/neos/cgi-bin/nph-neos-
solver.cgi?admin=results&jobnumber=4679195&pass=JMNRQoTD

Job 4679195 dispatched
password: JMNRQoTD

----- Begin Solver Output -----

Job submitted to NEOS HTCondor pool.
```

AMPL Interactive Session

```
----- Begin Solver Output -----
```

```
Job submitted to NEOS HTCondor pool.
```

```
CPLEX 12.6.2.0: optimal integer solution; objective 265.9999999999943
```

```
135348 MIP simplex iterations
```

```
17430 branch-and-bound nodes
```

```
ampl: option omit_zero_rows 1, display_1col 0;
```

```
ampl: display Work;
```

```
Work [*] :=
```

```
  1 16    11 16    36 19    72 20    82 20    106 16    114 20    125 20
```

```
  3 16    29 16    66 17    79 19    104 19    112 16    121 16
```

```
;
```

```
ampl:
```

NEOS Server

Kestrel Impact

Some success

- 2013 and 2014:
Peaked at over 500,000 submissions
- 2015:
Dropped to only about 30,000 submissions

Kestrel Assessment

Strengths

- Powerful local client for modeling
- NEOS facilities for solving

Weaknesses

- Limited support & development
- Not all NEOS solvers available
- Competition with local solver software
 - * Bundled with modeling languages
 - * Free for trial use
 - * Free for course and academic use

More Recently . . .

NEOS in Solver Studio

- Excel add-in using
AMPL/GAMS models, NEOS solvers

Optimization Services

- Fully distributed, decentralized alternative to NEOS

Gurobi Cloud Services for Optimization

- Original Gurobi cloud
- **Gurobi compute service cloud**

IBM Decision Optimization on Cloud

- “DropSolve” service similar to NEOS
- “DOcplexcloud API” like NEOS API

Gurobi Cloud

www.gurobi.com/documentation/6.5/cloud-guide/

Client side

- Any version of Gurobi
- Licensed for front-end use only

Server side

- Gurobi compute server for MIP
 - * Single-machine solves with one or multiple servers
 - * Distributed MIP
 - * Distributed concurrent MIP
 - * Distributed tuning
- Amazon Web Services hosts

*“Cloud computing technology is changing quickly.
Please check these documents periodically to ensure
you have the latest instructions for the Gurobi Cloud.”*

Gurobi Cloud for AMPL

Client side

- AMPL command-line or IDE environment
- Gurobi for AMPL, using front end only

Server side

- Gurobi compute server running MIP solver
- One Amazon Web Services host

. . . aka Gurobi Instant Cloud

Gurobi Cloud for AMPL

cloud.gurobi.com/app

The screenshot shows the Gurobi Cloud for AMPL web application interface. The browser address bar displays `https://cloud.gurobi.com/app`. The page features a dark navigation bar with the Gurobi logo and menu items: PRODUCTS, DOWNLOADS, RESOURCES, ACADEMIA, SUPPORT, and ABOUT. A search bar is also present. Below the navigation bar, there are tabs for Home, Getting Started, Pricing, and Launcher. The main content area is divided into two sections:

- Account info:** This section displays user details: Email (4er@ampl.com), Cloud License (121420), Rate Plan (Free Trial), and License Balance (\$ 25.00). It includes buttons for License usage and API access.
- Launch control:** This section allows users to configure and launch a machine. It includes a License Type dropdown (set to Light), an Idle Shutdown field (set to 60 minutes), and a Confirm and launch 1 machine button.

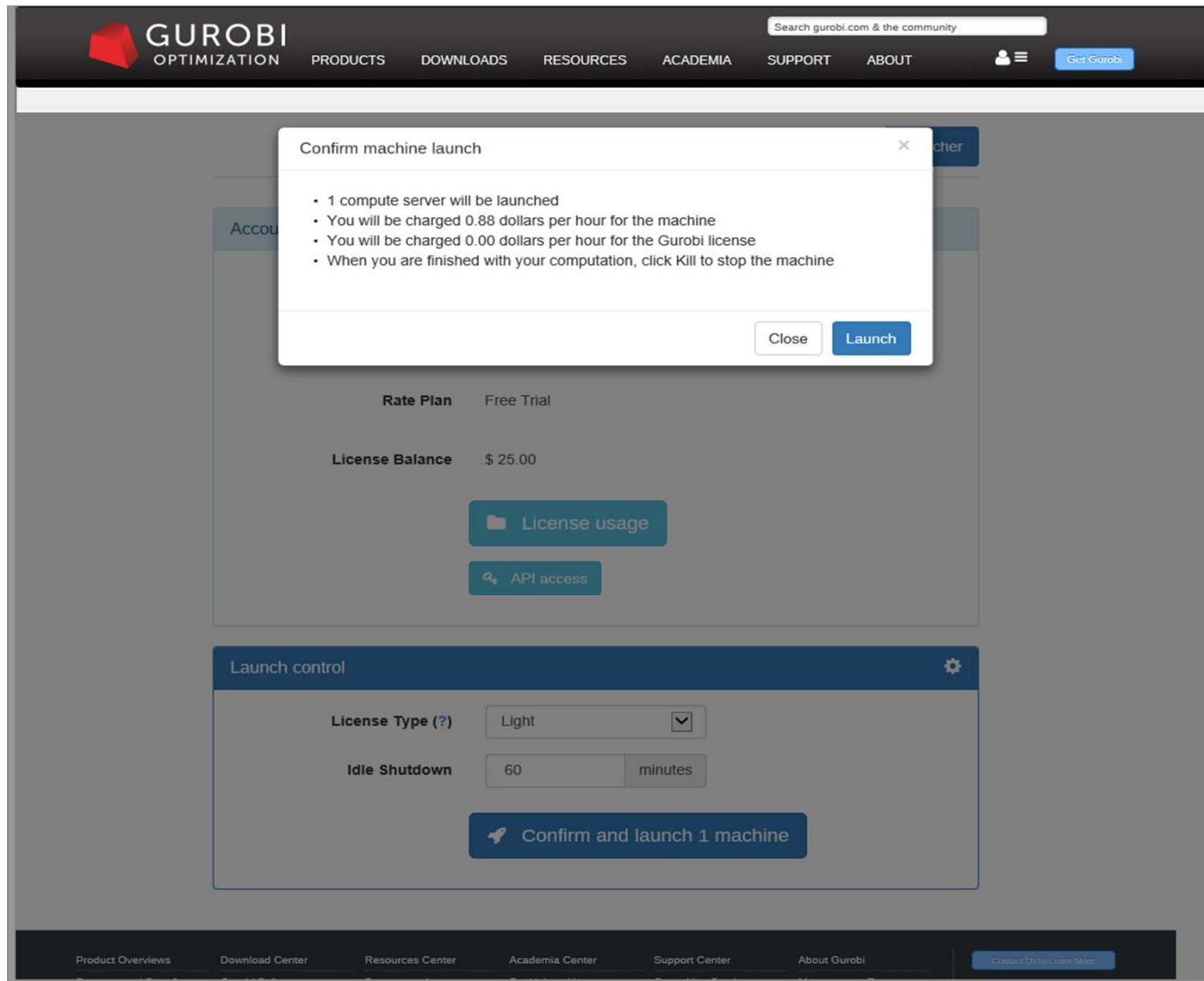
The footer contains links for Product Overviews, Download Center, Resources Center, Academia Center, Support Center, and About Gurobi, along with a Contact Us to Learn More button.

Gurobi Cloud for AMPL

cloud.gurobi.com/app

The screenshot shows the Gurobi Cloud for AMPL web application interface. At the top, there is a dark navigation bar with the Gurobi logo (a red cube) and the text "GUROBI OPTIMIZATION". To the right of the logo are navigation links: "PRODUCTS", "DOWNLOADS", "RESOURCES", "ACADEMIA", "SUPPORT", and "ABOUT". A search bar contains the text "Search gurobi.com & the community". A "Get Gurobi" button is located on the far right of the navigation bar. Below the navigation bar, there is a secondary navigation bar with links for "Home", "Getting Started", "Pricing", and "Launcher". The "Launcher" link is highlighted with a blue background. The main content area is divided into two sections. The first section, titled "Account info", displays the following information: "Email" is 4er@AMPL.com; "Cloud License" is 121420 (with a dropdown arrow); "Rate Plan" is Free Trial; and "License Balance" is \$ 25.00. Below this information are two buttons: "License usage" (with a folder icon) and "API access" (with a magnifying glass icon). The second section, titled "Launch control", has a blue header with a gear icon. It displays: "License Type (?)" is Light (with a dropdown arrow); "Idle Shutdown" is 60 minutes; and a large blue button labeled "Confirm and launch 1 machine" with a rocket icon. At the bottom of the page, there is a dark footer bar with links for "Product Overviews", "Download Center", "Resources Center", "Academia Center", "Support Center", and "About Gurobi". A "Contact Us to Learn More" button is located on the far right of the footer bar.

Confirm and Launch



Wait for Machine to Start Running

The screenshot shows the Gurobi Cloud for AMPL interface. At the top, there is a navigation bar with the Gurobi logo and menu items: PRODUCTS, DOWNLOADS, RESOURCES, ACADEMIA, SUPPORT, ABOUT. A search bar and a 'Get Gurobi' button are also present.

The main content area is divided into several sections:

- License Information:** Displays the user's email (4er@ampl.com), Cloud License (121420), Rate Plan (Free Trial), and License Balance (\$ 25.00). There are buttons for 'License usage' and 'API access'.
- Launch control:** A section with a gear icon for settings. It includes a 'License Type (?)' dropdown set to 'Light' and an 'Idle Shutdown' field set to '60 minutes'. A large blue button reads 'Confirm and launch 1 machine'.
- Machine list:** A table showing the status of the launched machine.

Machine Name	Type	State	Time Started
Waiting for machine to start running		obtaining license	2 minutes ago

At the bottom, there is a footer with links for Product Overviews, Download Center, Resources Center, Academia Center, Support Center, About Gurobi, and a 'Contact Us to Learn More' button.

Get Machine Name and Password

The screenshot shows the Gurobi Cloud web interface. At the top, there is a navigation bar with the Gurobi logo and menu items: OPTIMIZATION, PRODUCTS, DOWNLOADS, RESOURCES, ACADEMIA, SUPPORT, ABOUT. A search bar is also present. Below the navigation bar, the main content area is divided into several sections:

- Launch control:** A panel with a settings icon. It contains a "License Type" dropdown menu set to "Light" and an "Idle Shutdown" input field set to "60" minutes. A blue button labeled "Confirm and launch 1 machine" is at the bottom.
- Machine list:** A table with columns "Machine Name", "Type", "State", and "Time Started". One machine is listed: "ec2-54-175-34-225.compute-1.amazonaws.com" with type "light" and state "idle", started "3 minutes ago". Below the table are two buttons: "Download license file" and "Kill 1 machine".
- Getting Started:** A section with a list of instructions:
 - To connect to your cloud machine you'll need to [download](#) and [install](#) the latest version of Gurobi.
 - Use the information below to connect and perform different tasks on your machine.
 - For further information about your remote machine see the following pages of the [Reference Manual](#):
 - [Gurobi Remote Services](#)
 - [Gurobi Remote Services and Compute Server Administration](#)
- Use the following command to solve a model:** A green box containing a terminal command:

```
gurobi_cl --servers=ec2-54-175-34-225.compute-1.amazonaws.com --password=2159c003 mymodel.mps
```

Get Gurobi License File

```
# This is a license file created by the Gurobi Instant Cloud
# Created on Thu, 28 Apr 2016 00:18:42 GMT
# License Id: 121420
# Place this file in the following locations:
#   * C:\gurobi\ on Windows
#   * /opt/gurobi/ on Linux
#   * /Library/gurobi/ on Mac OS X
# Or set environment variable GRB_LICENSE_FILE to point to this file

COMPUTESERVER=ec2-54-175-34-225.compute-1.amazonaws.com
PASSWORD=2159c003
```

Gurobi Cloud for AMPL

Ready for Use with AMPL

```
ampl: model multmip3.mod;
ampl: data multmip3.dat;

ampl: option solver gurobi;

ampl: option gurobi_options \
    'server=ec2-54-175-34-225.compute-1.amazonaws.com \
     server_password=2159c003';

ampl: solve;

Gurobi 6.5.0: server=ec2-54-175-34-225.compute-1.amazonaws.com
server_password=2159c003

Server capacity available on
ec2-54-175-34-225.compute-1.amazonaws.com - running now

Gurobi 6.5.0: optimal solution; objective 235625
266 simplex iterations
21 branch-and-cut nodes plus
34 simplex iterations for intbasis

ampl: display Trans ...
```

Gurobi Cloud for AMPL

Check Charges

The screenshot displays the Gurobi Cloud web interface. At the top, there is a navigation bar with the Gurobi logo and menu items: OPTIMIZATION, PRODUCTS, DOWNLOADS, RESOURCES, ACADEMIA, SUPPORT, ABOUT, and a 'Get Gurobi' button. A search bar is also present. The main content area features a modal window titled 'Usage for License 121420'. This window contains a table with the following data:

Start Time	Hours	Region	Hostname	License Type	Instance Type	Machine Charge	License Hours
2016-04-28 00:16:25	* 0.39	us-east-1c	ec2-54-175-34-225.compute-1.amazonaws.com	light	c4.4xlarge	\$0.882	0.50

Below the table, it indicates '* currently running'. At the bottom of the modal, there are two buttons: 'License statement' and 'Close'. In the background, the main interface shows a 'License Balance' of \$ 24.12, a 'License usage' button, an 'API access' button, a 'Launch control' section with a dropdown for 'License Type (?)' set to 'Light', an 'Idle Shutdown' field set to '60 minutes', and a 'Confirm and launch 1 machine' button. A 'Machine list' table is partially visible at the bottom.

Gurobi Cloud Costs

Gurobi license fees

- \$10/hour/socket single-use
- \$20/hour/socket unlimited

. . . based on solve times

Amazon machine fees

- \$0.11/hour for minimal machine
- \$1.76/hour for highest-speed machine
- \$2.80/hour for highest-memory machine

. . . based on time machine is active

Discounts and special rules . . .

Gurobi Cloud for AMPL: Assessment

Strengths

- Security
- Reliability (via Amazon)
- Support for multi-server pools
- Support for local modeling clients

Drawbacks (compared to NEOS)

- Licensing issues
 - * Currently needs full “Gurobi for AMPL” license
- Separate server management (via Amazon)
 - * Complicated to set up
 - * Complicated pricing
- Specific to one solver

. . . short of “optimization on demand”