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# Cloud Services for Optimization Modeling Software

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# 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
- Client application run by the user on local processors

## *Server side*

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

## *Not considered here . . .*

- User logged in to the remote computer
- Server side managed 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*

*Two main examples . . .*

## *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 / instructive recent offering

*. . . both offer modeling language interfaces*

# **NEOS Server** [www.neos-server.org](http://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
- Several 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 varied inputs & solvers
- Process submissions on demand
- Contributed by varied organizations

## *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 of programs

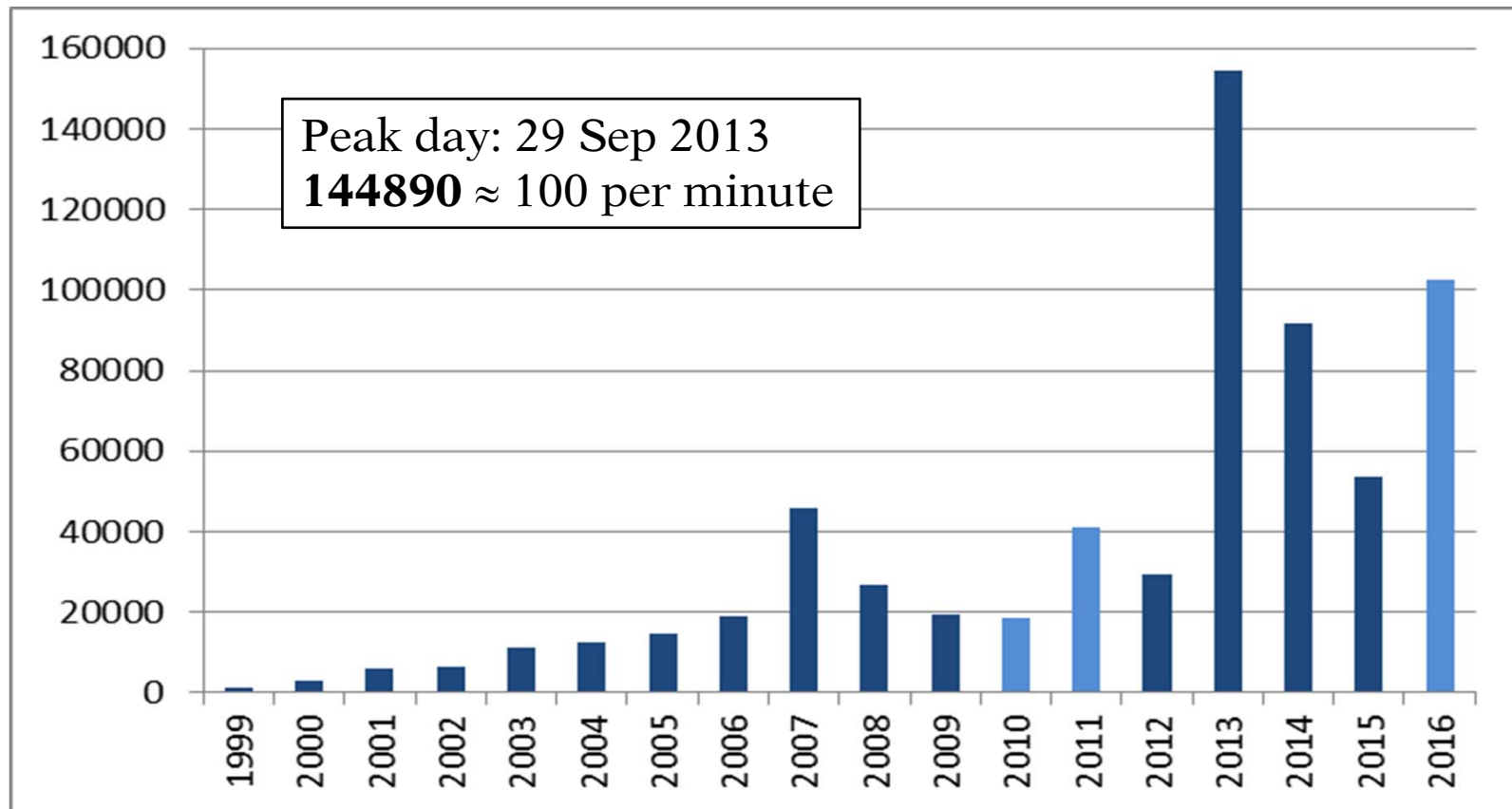
W. Gropp and J.J. Moré, 1997. **Optimization Environments and the NEOS Server**. *Approximation Theory and Optimization*, M. D. Buhmann and A. Iserles, eds., Cambridge University Press, 167-182.

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*

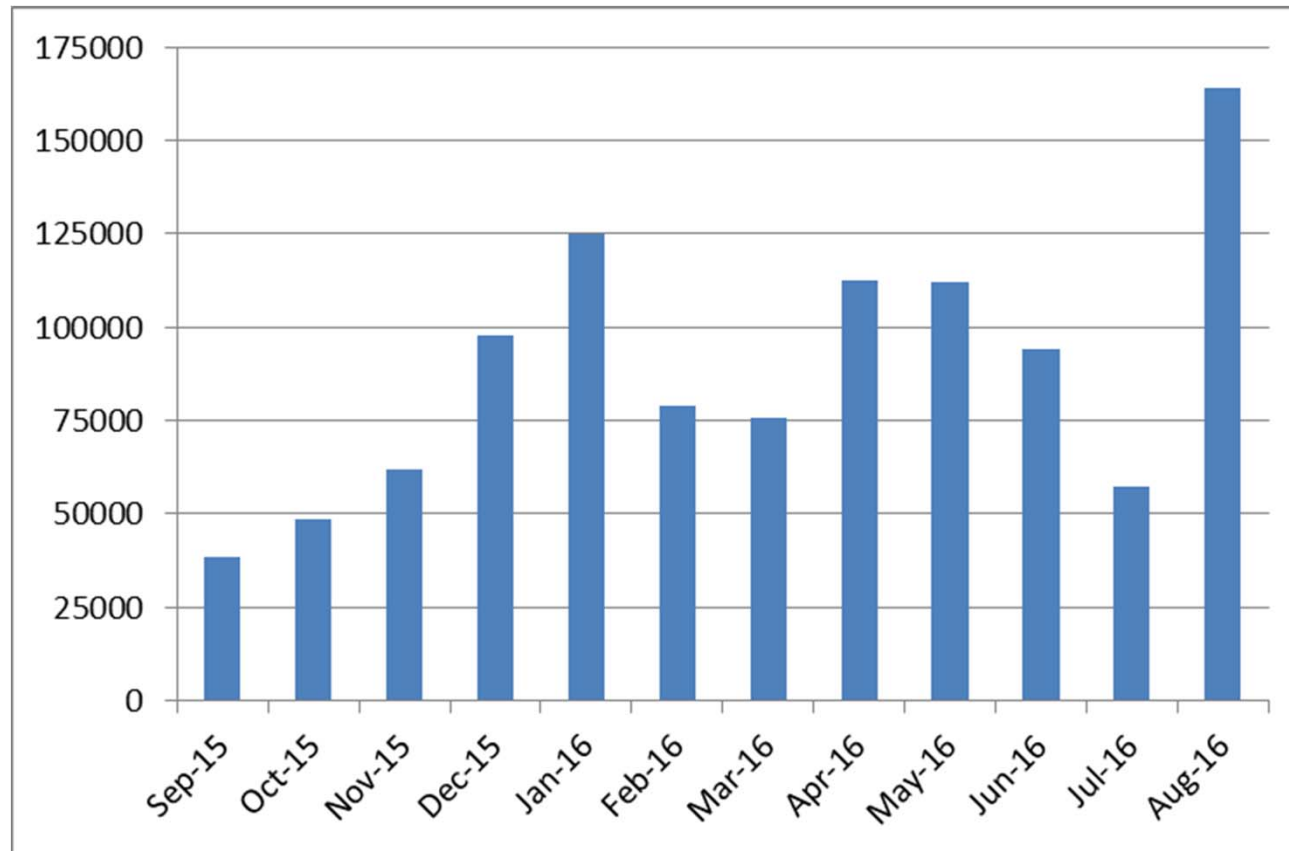


*45000/month  $\approx$  one per minute*

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 focus: submission of “solve jobs”
- Non-profit management
  - \* Limited support & development
  - \* No guarantee of confidentiality
  - \* No guarantee of performance

## **Recent Enhancements**

### *More flexible workstation infrastructure*

- Based on HTCondor “high-throughput computing”

### *Secure user authentication*

- Option to register and sign in when submitting
- Potential advantages for registered clients
  - \* priority job execution
  - \* data security
  - \* “more services and better customized experiences”

# Modeling Languages in NEOS

## *Modeling language inputs*

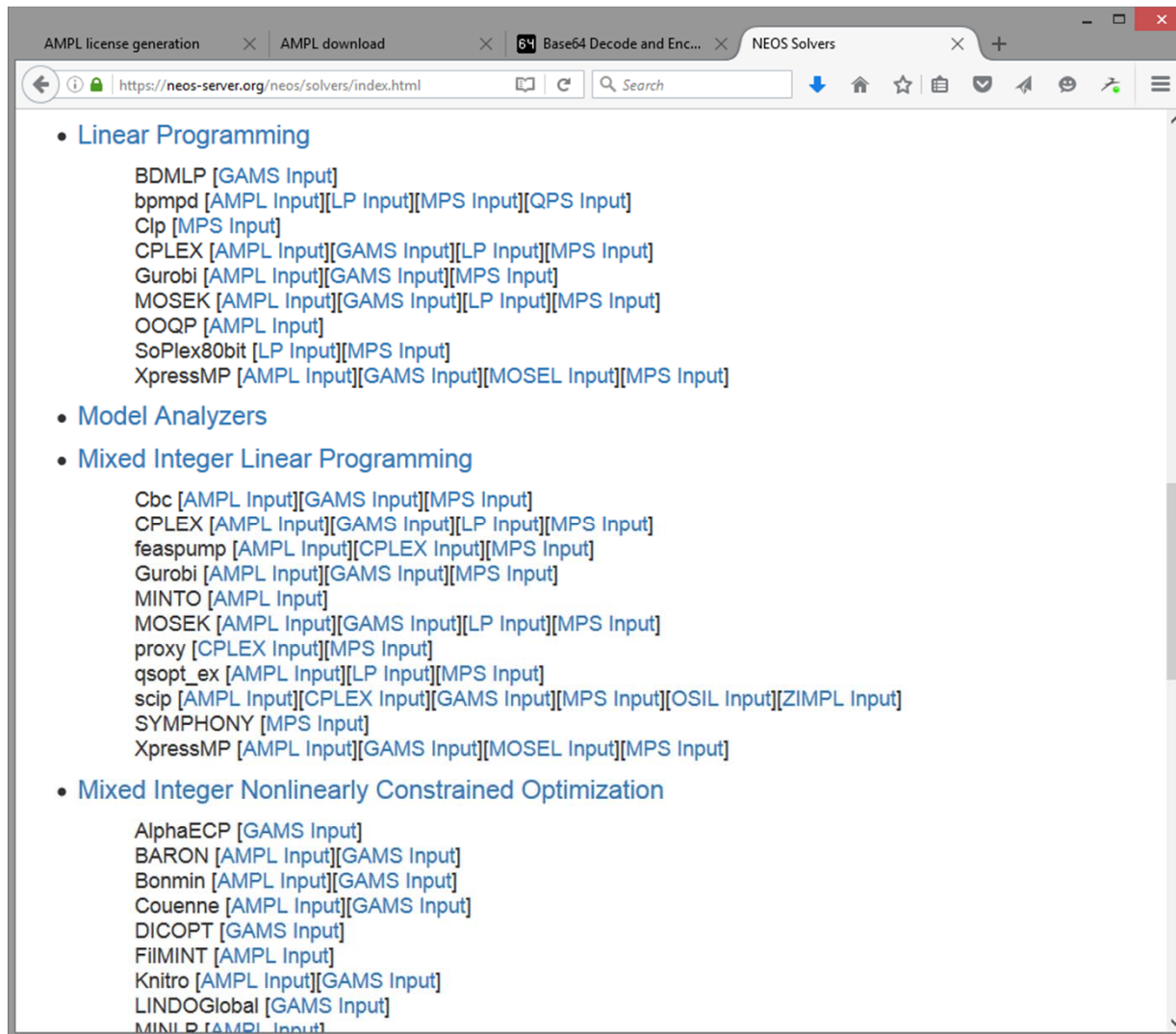
- AMPL model, data, commands files
- GAMS model, options,.gdx files

## *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](http://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 URL and a search bar. The page header includes the NEOS logo, navigation links for 'Contact' and 'Help', and buttons for 'Sign In' and 'Sign Up'. A large banner features the NEOS logo and the word 'Optimization' in a stylized font. Below the banner, the text reads 'NEOS Interfaces to CPLEX' and provides links for 'WWW Form & Sample Submissions', 'Email', and 'XML-RPC'. The main content area is titled 'CPLEX' and contains text describing the NEOS Server's capabilities for solving linear programming problems using the CPLEX Optimizer. It also includes a section titled 'Using the NEOS Server with AMPL/CPLEX' with detailed instructions and a note about email requirements for submissions.

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 sections for file selection:

- Model File:** "Enter the location of the AMPL model file (local file)" with a text input field and a "Browse..." button.
- Data File:** "Enter the location of the AMPL data file (local file)" with a text input field and a "Browse..." button.
- Commands File:** "Enter the location of the AMPL commands file (local file)" with a text input field and a "Browse..." button.

At the bottom, there is a **Comments:** section with a large text area for user input.

NEOS Server

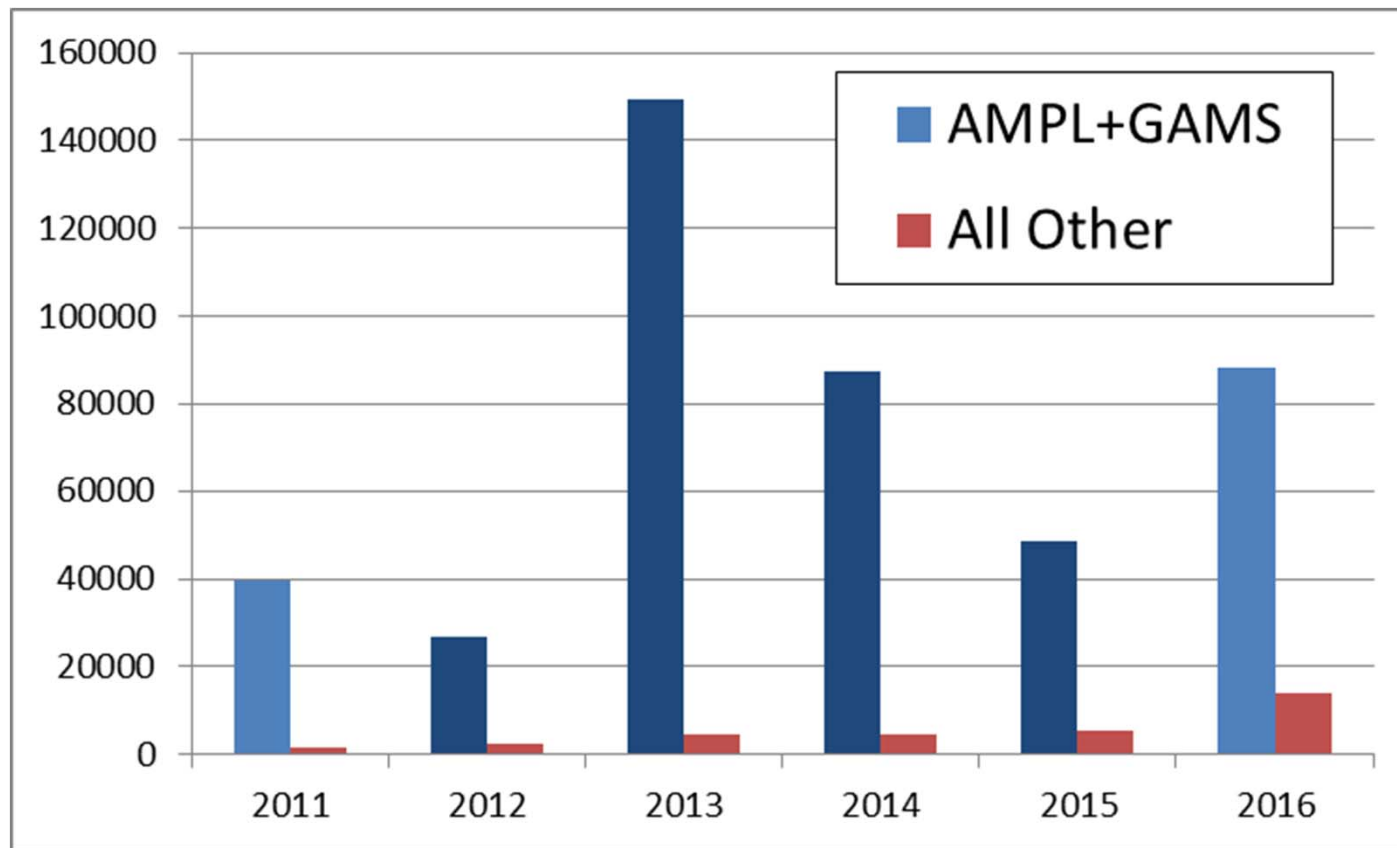
# AMPL Input Page

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 area 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 a text input field labeled "e-mail address:". A paragraph 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 the text "Comments and Questions · [Terms of Use](#)" and logos for "WISCONSIN" and "WISCONSIN INSTITUTES FOR DISCOVERY". The copyright notice at the very bottom reads: "Copyright © 2016, [Wisconsin Institutes for Discovery](#) at the University of Wisconsin, Madison · [Terms of Use](#)".

NEOS Server

# Impact: Modeling Languages

*Monthly rates since 2011*



# **Assessment: Modeling Languages**

## *Strengths*

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

## *Weaknesses*

- Lacks interactive features of modeling systems

*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 systems**

*NEOS Server*

# NEOS in Modeling Systems

## *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
- 2016:  
Up to over 90,000 submissions in first 8 months

# **Kestrel Assessment**

## *Strengths*

- Powerful local client for modeling
- NEOS facilities for solving

## *Weaknesses*

- Limited support & development
- Not all NEOS solvers available
- Local solver software is strong competition . . .
  - \* 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

## *IBM Decision Optimization on Cloud*

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

## *Gurobi Cloud Services for Optimization*

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

# Gurobi Cloud

[www.gurobi.com/documentation/6.5/cloud-guide/](http://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.

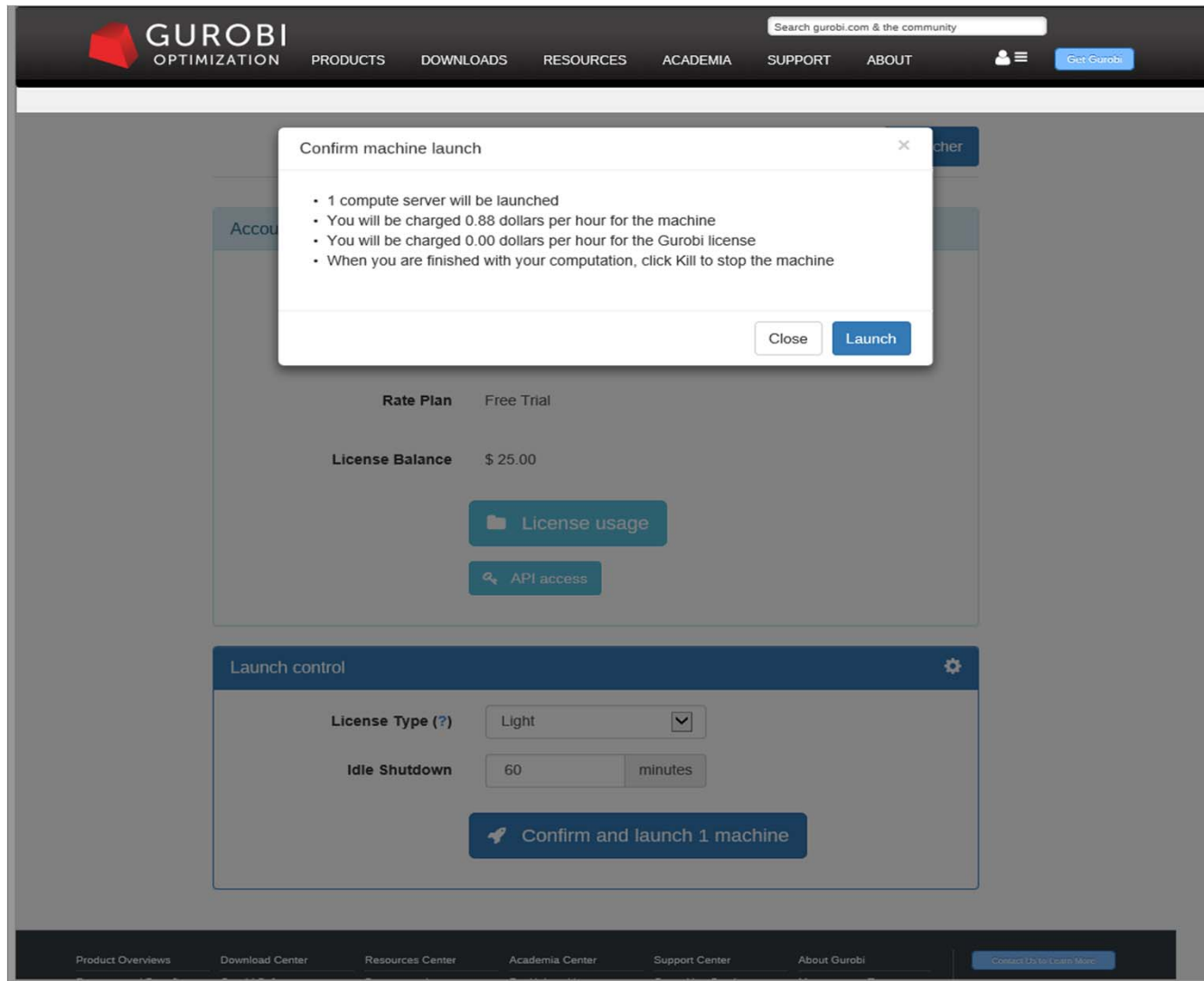
The footer contains links for Product Overviews, Download Center, Resources Center, Academia Center, Support Center, and About Gurobi, along with a Contact Us to Learn More button.

*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 in the top right corner. 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 (with a text input field and a "minutes" label). Below this information is a large blue button with a rocket icon and the text "Confirm and launch 1 machine". 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 in the bottom right corner of the footer.

# Confirm and Launch





# Wait for Machine to Start Running

The screenshot displays the Gurobi Cloud for AMPL user interface. At the top, the Gurobi logo and navigation menu are visible. The main content area is divided into three sections:

- License Information:** Shows the user's 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:** Allows configuration of the license type (set to "Light") and idle shutdown time (set to 60 minutes). A "Confirm and launch 1 machine" button is present.
- 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

# Get Machine Name and Password

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, and ABOUT. A search bar is located on the right side of the navigation bar. Below the navigation bar, the main content area is divided into several sections:

- Launch control:** This section contains a dropdown menu for "License Type" set to "Light" and a text input for "Idle Shutdown" set to "60" minutes. A blue button labeled "Confirm and launch 1 machine" is positioned below these controls.
- Machine list:** This section displays a table with the following data:

Machine Name	Type	State	Time Started
ec2-54-175-34-225.compute-1.amazonaws.com	light	idle	3 minutes ago

Below the table, there are two buttons: a blue "Download license file" button and a red "Kill 1 machine" button.
- Getting Started:** This section provides instructions on how to connect to the cloud machine, including links to the Reference Manual and Gurobi Remote Services.
- Use the following command to solve a model:** This section contains a code block with the following 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 modal 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 are buttons for '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' and 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 with columns for 'Machine Name', 'Type', 'State', and 'Time Started'.

# 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
  - \* Need to run Gurobi locally *and* in the cloud
- Separate server management (via Amazon)
  - \* Complicated to set up
  - \* Complicated pricing
- Specific to one solver

*... short of “optimization as an internet resource”*