



GAMS Anytime Courses & Workshops

– Modeling and Optimization with GAMS –

From November 2021 on, we offer – in addition to the annual **physical** basic and advanced course – a new and additional concept which allows you to freely select **content, duration & time, location, mode, and type**:

Content: You can **specify blocks of content** from the standard physical courses (see details in the PDF), but you can express wishes for extra blocks and topics, among them, for instance, modeling and optimization under uncertainty, modeling supply network problems, optimization in metals, paper or process industry. Free content also allows you weighting the focus of GAMS language & system, modeling and optimization algorithms and solver. Within GAMS language & system, the focus could be on developing stable industrial applications, modularity within GAMS, GAMS Miro, or interfacing to other packages.

Duration and time: Duration varies between 2 and 5 days. Time to be agreed on.

Location: It can be a) at your company or institutional location (you organize),
b) any reasonable meeting hotel (you organize), or
c) Hotel Speeter in Weisenheim am Berg, Germany,
only one hour away from Frankfurt airport. (<http://www.hotel-speeter.de/>).
The hotel is located in a picturesque village at the Deutsche Weinstraße and offers free parking and free WLAN access to the course participants.

Mode: **Physical events** and **hybrid** (buy the event material and contract a specified number of (individual) online support hours. We do not offer full online courses.

Type: **Course**, a **workshop**, or a mixture of both. Courses have a rather strict course structure (as my standard courses), while a workshop offers more flexibility for instance, to discuss and analyze your model or optimization problem at hand, to screen your model or to tune your model formulation to show better performance.

Offering:

- Event material via download server (GAMS, presentations, examples, literature)
- Full GAMS software with several solvers (temporary license for 2 months)
- Analysis and consulting on participants' problems.
- Participants have access to the complete course material prior to the event.
- Course & Workshop Language: German or English. All course material will be in English. Material produced explicitly for the workshop can also be in German.

For details (duration & time) and initializing an event contact me via JosefKallrath.SC@sci-con.de



GAMS Courses 2023

– Modeling and Optimization with GAMS – Course Menu or Course à la Carte

The following pages serve as an orientation of what you you may select as the **Course Menu** or a **Course à la Carte**. Just inspect the basic (p. 2) and advanced courses (p. 6):

Location: Hotel Speeter, Weisenheim am Berg, Germany, only one hour away from Frankfurt airport. (<http://www.hotel-speeter.de/>).
The hotel is located in a picturesque village at the Deutsche Weinstraße and offers free parking and free WLAN access to the course participants.

Pickup & transfer by a limousine service from/to Frankfurt airport or from/to Mannheim train station is available at a one-way cost of approx. 100 or 40 Euro, resp. We recommend to book this with the course registration.

Iternative: For those, who cannot attend a in-person course, I sell the course material at half the price and offer individual online-hours at a rate of 200 €/hour. Please, contact me to find out more about this option.

Offering (Full board only for courses at hotel Speeter, books for physical courses):

- Course material via download server (GAMS, presentations, examples, literature)
- Full GAMS software with several solvers (temporary license for 2 months)
- One of the following books: Book „Gemischt-Ganzzahlige Optimierung in der Praxis“ (Josef Kallrath, Vieweg 2012), or alternatively, „Business Optimization Using Mathematical Programming“ (Josef Kallrath & John M. Wilson, Macmillan) - PDF only as the book is out of print [second edition is in preparation]
- Full board (3 nights Sun-Tue, 3 x breakfast, 3 x lunch, 2 x dinner (Mo,Tu) – basic
- Full board (2 nights Wed-Thu, 2 breakfasts, 2 lunch, 1 dinner) – advanced course
- Free analysis and consulting on industrial participants' problems (send them in early; this offering does not apply to participants from universities or students)
- Participants have access to the complete course material prior to the course
- Course Language: English. All course material will be in English.

Course Fees include accommodation, food and beverages:

- Specified on the registration form (last page of this document).
- Discounts on early registrations, or combined courses registration.

Registration:

- Fax the signed form (last page of this document) to GAMS GmbH
- or send your registration data by e-mail to info@gams.de



Basic GAMS Course – Modeling and Optimization with GAMS –

Summary: GAMS Basic Course

This 3-days course helps the beginner/novice to become familiar with GAMS and to obtain the knowledge to model and solve simple optimization problems. The participants will get an orientation on mathematical optimization, *i.e.*, modeling and solution algorithms. After the course, the participants will be able to map decision problems to the basic objects of optimization models: indices, data, variables, constraints and objective functions. The course does not assume the participants to have any knowledge on GAMS if they have used already other programming languages.

Besides presentation, examples and hands-on activities the course leaves enough time for discussions and own problems of the participants to be analyzed.

Target group of participants

The course is ideal for participants who have either some elementary mathematics background, or have already done their first steps with GAMS, or have used another programming language for at least 6 months and wish to

- get an overview and introduction on mathematical optimization
- become familiar with the basic concepts of index sets, indices, variables, constraints and objective functions, and how to use these objects in GAMS
- get an overview on GAMS and how to use it to solve optimization problems
- learn how to model and to implement optimization problems in GAMS
- bring their own optimization problems (the course offers a free analysis and, if possible a first implementation).

The participants may prepare their participation by communicating and specifying what they expect from this course and what sort of problems they want to solve. The course is a challenge for participants with no mathematics background, no programming experience and no elementary GAMS knowledge.

Things to Do Before the Course

The course will be conducted on laptops of the participants. It is recommended that your laptop has administration rights in case some adjustments are needed. Note that GAMS, the course software, examples, presentations and useful literature will be distributed by a download server prior to the course. Please, install GAMS on your machine and **work yourself through the presentations to prepare for the course.** Tell us about your expectations, fields of interest and problems prior to the course.



Part 1: Overview & Basic Objects in GAMS

Day 1: (9:30-17:50) – starting with Registration (coffee, tea, refreshments)

Session 1a: Welcome and Introduction (9:30-10:00)

- Introduction, course objectives, expectations of the participants
- Overview, the presentations and other materials
- Course structure on the CD, Preparing the Laptops

Session 1b: Foundations of Mathematical Optimization (10:00-11:15)

- Optimization models and solution algorithms
- Algebraic modeling languages
- A simple example about cows and pigs

Coffee break (11:15-11:30)

Session 1c: Overview - Modeling with GAMS (Part I) (11:30-12:30)

- The structure of a GAMS Program:
- Indices, variables, constraints and objective functions
- Model declaration, conditional operators, \$, and, or, ...
- Solve statement, interpretation of *.log and *.lst files and *.log files

Lunch break (12:30-14:00)

Session 1c: Overview - Modeling with GAMS (Part II) (14:00-15:00)

- GAMS Studio / GAMS IDE and the Cows & Pigs Example – Exercise
- GAMS IDE – The old interface (* optionally *)
- Inspecting GAMS symbols in GDX files

Session 2a: Sets (15:00-16:10)

- Simple Sets and Multi-dimensional sets
- Subsets and domain checking
- Operations on Sets, operations on set elements, Dynamic Sets

Coffee break (16:10-16:30)

Session 2b: Data Objects (16:30-17:50)

- Scalars, Scalars, parameters and tables
- Exercise: Cows & Pigs using Sets & Parameters and working with GDX files
- Operations on scalars and parameters
- Exercises: Demand given per day and product – 6 tasks

Dinner (18:00-19:30, Restaurant Speeter)



Day 2: (9:30-17:45)

Session 3a: Variables (09:30-10:00)

- Declarations
- Attributes and assignment statements
- Display and variables in *.lst files
- Using the solution values of variables

Session 3b: Equations and Inequalities (10:00-11:30)

- Declarations & Definitions
- Model declaration, Conditional operators, \$, and, or, ...
- ----- coffee break embedded in this exercise -----
- Exercises Boat: Model Building, implementation & debugging, interpretation

Session 3c: Option Statement and Solver Communication (11:30-12:30)

- GAMS Options: Solver (reslim, optcr, optca)
- Feedback mechanisms GAMS & Solver
- What you get after COMPILE / What you get after RUN
- Exercises: NLPexercise

Lunch break (12:30-14:00)

Session 3d: Exercises: Modeling & Debugging (14:00-15:15)

- Exercises Cutstock: Model Building and Implementation
- Exercises Cutstock: Debugging Compilation Errors

Session 4a: Conditional Expressions (15:15-16:00)

- Using the \$ Symbol in Conditional Expressions
- Logical Operators
- Exercises: Modifying the transport problem

Coffee break (16:00-16:20)

Session 4b: Procedural Language Elements (16:20-17:50)

- For, If, Loop, Repeat and While
- Exercise on FOR/WHILE: Complete Enumeration (Cows-Pigs)
- Exercises on IF/WHILE : Analyzing the points collected by a soccer team
- \$Exit, \$Goto and \$Label Statement

Dinner (18:00-19:30, Restaurant Speeter)



Day 3 (09:30-17:45)

Session B5a: Input Simple Text Files (09:30-10:40)

- Feeding data into GAMS
- Reading csv-files (\$ondelim, \$offdelim)
- Exercises: Read the data from the “Cutstock” example from file

Coffee break (10:40-11:00)

Session B5b: Output of Simple Text Files (11:00-12:25)

- Put & Write facilities
- Formatted output
- Report Generation: Put & Write-Facilities, Advanced Formatting, Put_Utilities
- Exercises: Output the results from the “Cutstock” example to files

Lunch break (12:30-14:00, Pfälzer Weinstuben Holz-Weisbrodt)

Session 6: GAMS Usage (14:00-15:30)

- GAMS Special Functions
- Compile-time versus Runtime Commands I - the \$ command
- Calling GAMS from Command Shells
- A Larger Application Example: Energy Portfolio Optimization

Coffee break (15:30-15:50)

Session 7: Exercises: Modeling & Debugging (15:50-17:20)

- Exercises: Model Building and Implementation
- Exercises: Debugging Compilation Errors
- Diagnosing Infeasibilities

Session 8: GAMS Resources & Final discussion (17:20-17:45)

- GAMS Lib, GAMS Utilities, GAMS Web, GAMS Wiki-Support
- Outlook into the Advanced Course
- Final discussion

End (17:45)

The agenda may change slightly !



Advanced Optimization Course – Modeling and Optimization with GAMS –

Summary: GAMS Advanced Course

This 2-days course helps the *mathematically inclined participants* to learn advanced techniques for better using GAMS to model and *solve larger or complicated optimization problems, especially, mixed integer optimization problems*. The participants will increase their knowledge on using GAMS efficiently and will learn more about procedural and modular language features, background on the solvers embedded in GAMS, how to interface to systems outside GAMS and how to use and create Function Libraries. The course assumes the participants to have some basic knowledge on GAMS and familiarity with the GAMS-IDE or GAMS Studio. For the *mathematical part of this course*, it helps if the participants have a decent mathematical background.

The participants will learn more about the *MILP, NLP and MINLP solvers* as well as on *global optimization techniques*. We stress that difficult and large optimization problems require a tight connection between modeling and algorithms aspects. This leads to *sequence of models, nested solve statements, and decomposition techniques* – detailed examples will be discussed. An important aspect of the course is the development of industrial applications software. The course will provide tricks-of-the-trade not covered by the GAMS documentation or other public sources.

Besides presentation, examples, hands-on activities and exercises the course leaves enough time for discussion and own problems of the participants to be analyzed.

Target group of participants

Ideally, participants with a good mathematics background or some years of GAMS experience. For the Advanced Course, only attendees are accepted who have attended the GAMS Basic Course or have at least 6 months experience with GAMS.

It is strongly recommended that participants of the Advanced Course also attend the Basic Course, even if they have used GAMS before. Experience over the last 12 years has shown that the first three days of the basic course put everybody on the same level, produce familiarity with a consistent approach on how to use GAMS, and that everybody benefits from the group dynamics and spirit of the course.

The advanced course is ideal for participants who wish to

- *solve large and difficult problems* and learn about approaches to attack them using *polyolithic modeling and solution approaches*
- *reduce computing time and memory requirements when solving difficult or large optimization problems*, or want to benefit from the *scenario solver GUSS*



- exploit the MIP restart feature in Cplex in sequences of models
- learn how to *transform apparently nonlinear optimization problems to linear ones*
- learn more about *nonlinear optimization and global optimization techniques*
- obtain insights into how the GAMS solvers among them Cplex, Gurobi, XpressMP, Conopt, Baron, Lindoglobal and others
- increase the efficiency with which they use GAMS
- use GAMS in a more modular way using macros, the batinclude command, and advanced compile time features, e.g., loops in compile time languages
- enhancing the usefulness of GAMS output, e.g., using the put_utilities
- learn about GDX, the GDX utilities and how link with other programs such as MS Excel or MS Access; special focus on how to extract data from MS Excel
- to find out about more powerful things GAMS can do that are not so well known because of hidden features or a lack of treatment in the documentation & tricks-of the trade
- to refresh their knowledge and learn more about more recent GAMS features
- bring their own GAMS models and problems (the course offers a free analysis and, in most cases, an improvement)
- repairing and fixing models which do not produce solutions as wanted
- get inspiration on how to solve very difficult and large problems by polyolithic methods combining LP, MILP, NLP, or MINLP with heuristics.

The participants may prepare their participations by communicating and specifying what they expect from this course and what sort of problems they want to solve.

Things to Do Before the Course

The course will be conducted on participants' laptops. Laptops should have administration rights in case some adjustments are needed. Note that GAMS, the course software, examples, presentations and useful literature will be distributed by a download link prior to the course. Please, install GAMS on your machine and **work yourself through the presentations to prepare for the course**. In many cases the GAMS-IDE and GAMS Studio will be used, in some cases we might run applications in a DOS command shell, or connect to Excel spreadsheets. And, last but not least, tell us about your expectations, fields of interest and problems prior to the course.



Part 1: LP & MILP / Procedural Structures / Sequential Models

Day 1: (9:30-17:45) -- starting with Registration (coffee, tea, refreshments)

Session 1a: Welcome and Introduction (9:30-9:45)

- Introduction, course objectives, expectations of the participants
- Overview, the presentations and other materials

Session 1b: Foundations and GAMS Solvers (09:45-11:00)

- Optimization problems and solution algorithms
- LP: Revised Simplex and Interior point methods
- MILP: Branch&Bound and Branch&Cut
- Warm-Up Exercise: Modeling a Set Covering Problem (1e)

Coffee break (11:00-11:20)

Session 1c-1: The Art of Modeling Optimization Problems (11:20-12:20)

- The art of modeling: BigM formulations, logical constraints, etc
- Equivalent linear formulations for special nonlinear problems (1e)
- Monolithic versus polyolithic models
– standard versus tailor-made solution techniques

Lunch break (12:20-13:30, Pfälzer Weinstuben Holz-Weisbrodt)

Session 1c-2: Programming Mathematical Algorithms in GAMS (13:30-14:45)

- Branching on special ordered sets and semi-continuous variables (1e)
- Procedural language elements in GAMS – Programming own B&B Schemes

Session 2a: GAMS Advanced Usage (14:45-15:30)

- Domain Check and Universe (*) Declaration
- Compile-time versus Runtime commands II (1e)
- Proper Indexing and Profiling
- Fast Hot Starts: Scenario Solver GUSS

Coffee break (15:30-15:50)

Session 2b: GAMS Advanced Procedural Language Elements (15:50-17:00)

- Sequences of models, modular structures in GAMS
- Macros and Subroutines in GAMS (\$macro & \$batinclude) (1e)



Session 3: Multi-criteria Optimization (17:00-17:20)

- Foundations of multi-criteria optimization and Goal Programming
- Successive Problem Solving:
 - several MODEL and SOLVE statements
 - evaluating the results of a solve statement & generating the next model

Session 4: Difficult and Large-Scale Problems I (17:20-18:00)

- What makes optimization problems difficult ?
- Column Enumeration and Column Generation
- Paper industry cutting stock example: Gilmore-Gomory approach (1e)

Dinner (18:00-19:30)

Additional Topics

Session E1b: Optimization under Uncertainty (09:30-10:30)

- Structure of Uncertainty
- Stochastic Optimization & Value of the Stochastic Solution (VSS)
- Chance Constrained Programming
- Robust Optimization

Session E1c: Scenario Trees (10:30-11:15)

- Generation of Scenario Trees
- Reduction of the Trees (SCENRED)
- Demonstrations



Part 2: NLP & MINLP & Global / Interfacing with GAMS / Hybrid Methods

Day 2: (09:00-17:45)

Session 5a: Foundations of NLP and GAMS NLP Solvers (09:00-10:15)

- Foundations of nonlinear optimization: NLP ; GAMS & NLP
- Efficient formulations of NLP-problems
- Example “Molecule” with Solvers: MINOS, ConOpt, CoinIPOPT, SNOPT
- Exercise: A nonconvex NLP problem – dependence on initial value (1e)

Session 5b: GAMS Function Library Facility (10:15-10:45)

- Using Function Libraries / Creating Own Function Libraries (*optional*)
- Programming Own Functions (*optional*) – Embedded Python (*optional*)

Coffee break (10:45-11:00)

Session 5c: MINLP & Global Optimization in GAMS (11:00-12:25)

- Foundations of and ideas in mixed integer nonlinear optimization (MINLP)
- Foundations of Global optimization techniques – Global Solvers in GAMS
- Examples: Molecule & Cutting circles from rectangles
- Exercise: MINLP – Convex versus Nonconvex (1e)

Lunch break (12:25-13:30, Pfälzer Weinstuben Holz-Weisbrodt)

Session 6a: GDX and the GDX Utilities (13:30-15:15)

- GDX and the GDX Utility (1e)
- GAMS – Excel: Data Import and Export (1e)

Session 6b: Interfacing with GAMS (15:15-15:45)

- Interfacing with GAMS
- Building Applications
- Running GAMS from Excel: Cutting Stock and other examples

Coffee break (15:45-16:15)

Session 7: Difficult and Large-Scale Problems II (16:15-17:15)

- Introduction and Examples to Hybrid methods and Fix-and-Relax Techniques
- Hybrid example: (1+1) Evolutionary Algorithm + LP (Supply Management)
- Genetic Algorithm example in GAMS – Solving a non-convex NLP problem

Session 8: Tricks, GAMS Resources & Final Discussion (17:15-17:45)

- Tricks-of-the Trade: how to do .. ? Parallelization ! Parallel Polyolithic M&S
- GAMS Resources: GAMSLib, GAMS Utilities, GAMS Web



About the Lecturer

Josef Kallrath obtained his PhD in astrophysics from Bonn University (Germany) in 1989. He is a professor at the University of Florida (Gainesville, FL, www.astro.ufl.edu/~kallrath), and solves real-world problems in industry using a broad spectrum of methods in scientific computing, from modeling physical systems to supporting decisions processes by mathematical optimization. He has written review articles on the subject, about 130 research papers in astronomy and applied mathematics, and several books on mixed integer optimization, as well as one on eclipsing binary stars. Among the books relevant to this course are

Business Optimization Using Mathematical Programming (J. Kallrath, 2021, Macmillan – Springer Nature, Cham Switzerland) – 2nd edition.

Gemischt-Ganzzahlige Optimierung in der Praxis (J. Kallrath, 2002 & 2012, Vieweg)

Modeling Languages in Mathematical Optimization (J. Kallrath, 2004, Kluwer)

Algebraic Modeling Systems: Modeling and Solving Real World Optimization
(J. Kallrath, 2012, Kluwer)

Real Optimization with SAP APO (J. Kallrath and T. I. Maindl, 2006, Springer)

Optimization in the Energy Industry (J. Kallrath, Panos M. Pardalos, S. Rebennack, and S. Scheidt, Editors, 2008, Springer)

Josef Kallrath is an experienced consultant and course-instructor with in-depth knowledge related to modeling and optimization systems. Josef Kallrath has been providing consulting services to a wide range of industries, including energy, metals, paper, process, refineries, and telecommunication. He leads the *Real World Optimization Working Group* of the German Operations Research Society. His current research interests are polyhedral modeling and solution approaches to solve large-scale or difficult optimization problems, for instance, by decomposition techniques such as column generation, or hybrid methods.

**Thanks for your interest.
We are looking forward to exciting courses.**
