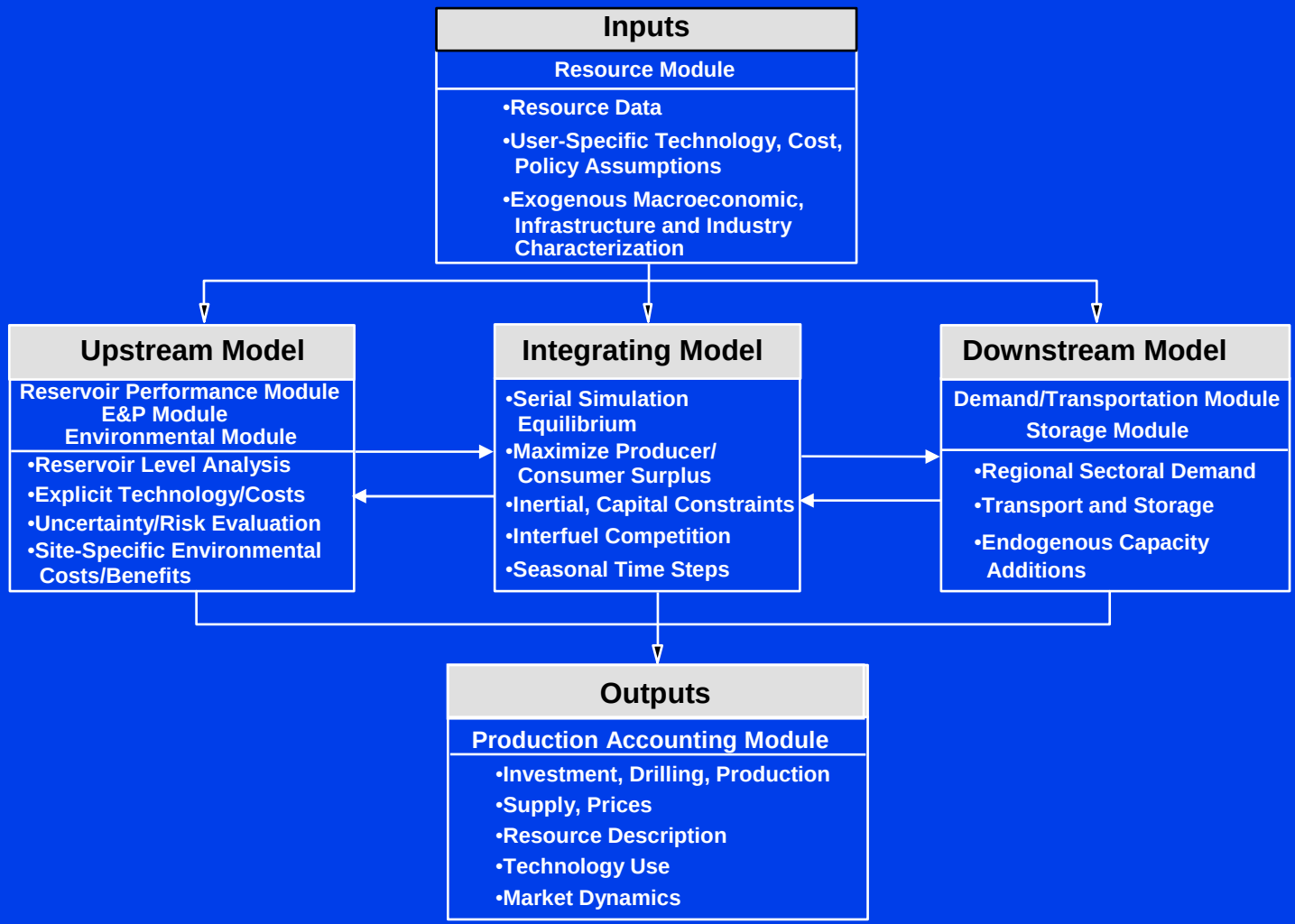
An Overview of the Gas Systems Analysis Model (GSAM)

January 12, 2000

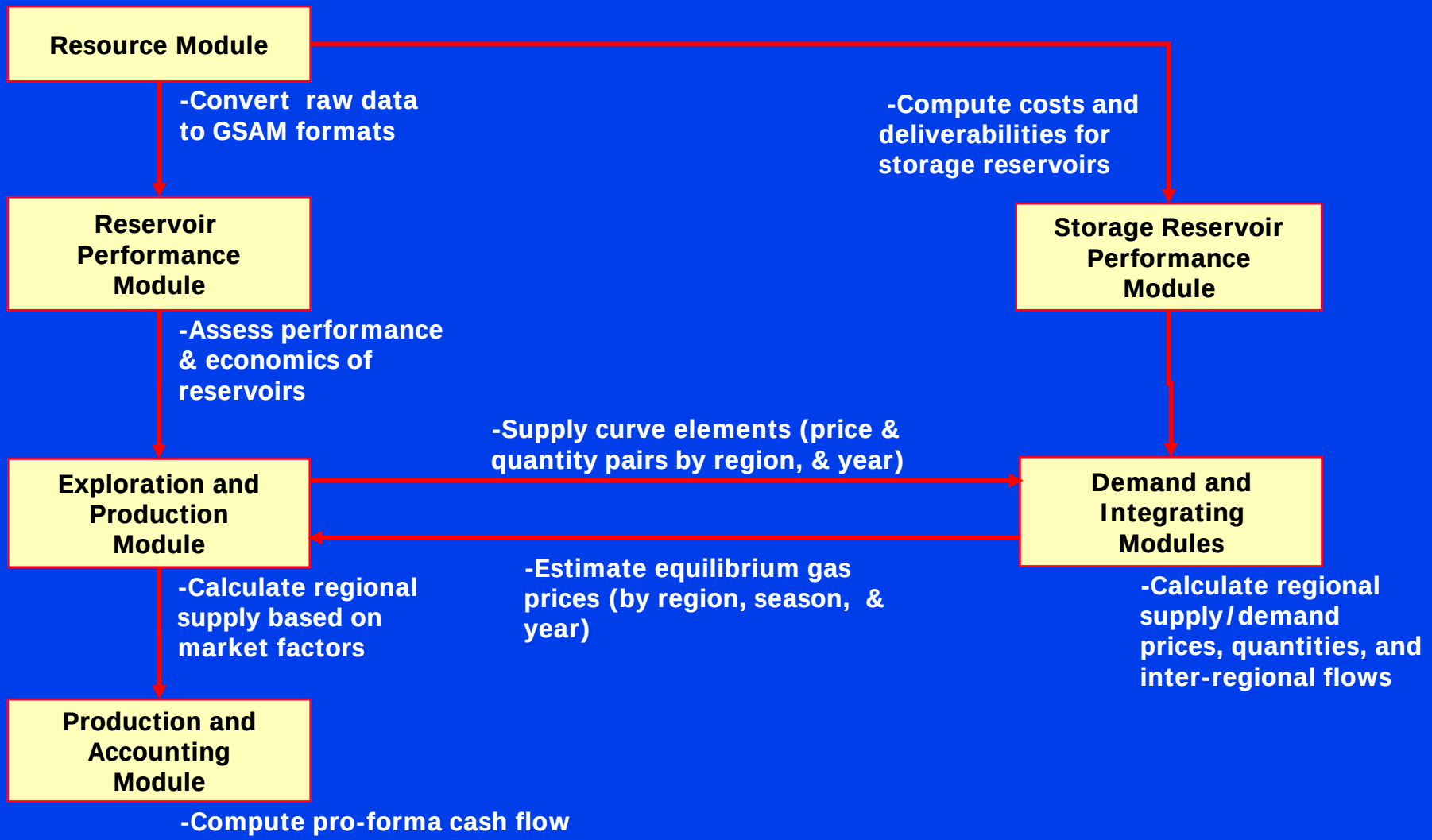
Overview of GSAM Development History

- Contract awarded 1992
- Prototype developed in late 1993; required input reservoir data base
- Initial design complete in June 1994
- Environmental module initiated in June 1994
- Data development task initiated in August 1994
- First peer-review meeting in October 1994
- Approved enhancements based on October 1994 review in February 1995
- Utilized for DOE metrics/planning September 1995 - June 1996
- Improvements to models and data implemented October 1996
- Testing, validation, and system enhancements based on first peer review
- Second peer-review meeting in February 1997
- Various system enhancements ongoing
- Applied for various DOE and EPA studies in 1997 and 1998
- Used for 1999 natural gas metrics study
- System applications ongoing (NPC environmental study, DOE federal access study)

GSAM Structure



GSAM Modules



Overview of GSAM Upstream Model

- **Upstream Model includes:**
  - Database of over 17,000 production reservoirs in North America so supply curves can be built from the "bottom up"
  - Database of several hundred storage reservoirs including computation of costs/deliverability for each facility
  - Type curves based on Darcy's Law for estimating flow
  - Modeling of the exploration and production activities based on economic behavior of each of the reservoir operators given contemporary market prices
  - Full pro-forma cash flow analysis and production values over time

Reservoir Database Elements in GSAM

Volumetric Data

- Productive Reservoir Area
- Porosity
- Net Pay
- Oil Saturation (Current, Initial)
- Water Saturation (Current, Initial)
- Gas Saturation (Current, Initial)
- Original Hydrocarbon-in-Place
- Total Area
- Temperature
- Pressure (Initial)

Geologic Variables

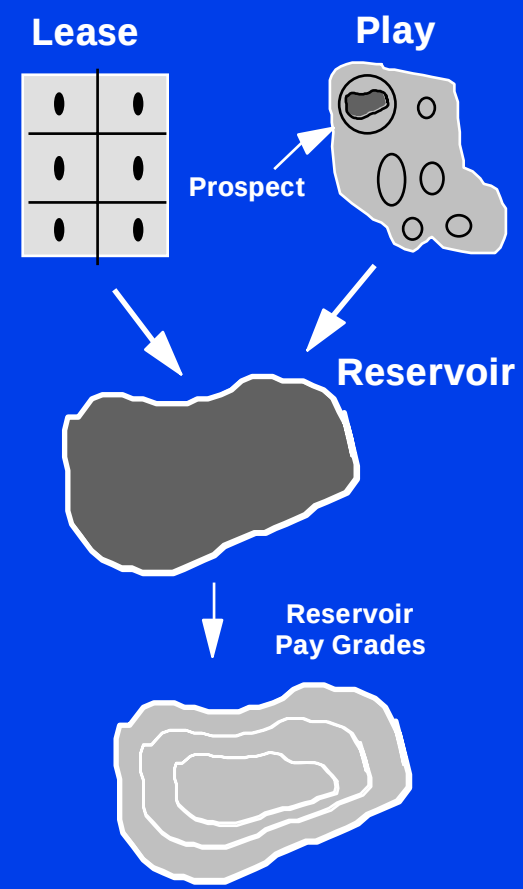
- Lithology
- Depth
- Permeability
- Clay Content
- Gross Thickness
- Dip Angle
- Geologic Age Code
- Structure, Faults, Shale Breaks
- Play, Depositional System, Trap Type
- Areal and Vertical Heterogeneity Descriptors
- Reservoir Continuity

Fluid Data

- Gravity
- Viscosity
- Formation Volume Factor
- Connate Water Viscosity
- Connate Water Salinity
- Gas-Oil Ratio (Current, Initial)
- Injection Water Salinity
- Hydrocarbons and Inert Fractions and Properties
- Composition Natural Gas Liquids
- Other PVT Data

Development and Performance Data

- Annual Production (Oil, NGL, Gas)
- Cumulative Production (Oil, NGL, Gas)
- Number of Wells
- Ultimate Recovery
- Recovery Efficiency
- Well Spacing
- Producing and Shut In Wells



GSAM's E&P Decision-Making Process Evaluates Project Opportunities at Each Stage of Development -- From Operator's Perspective

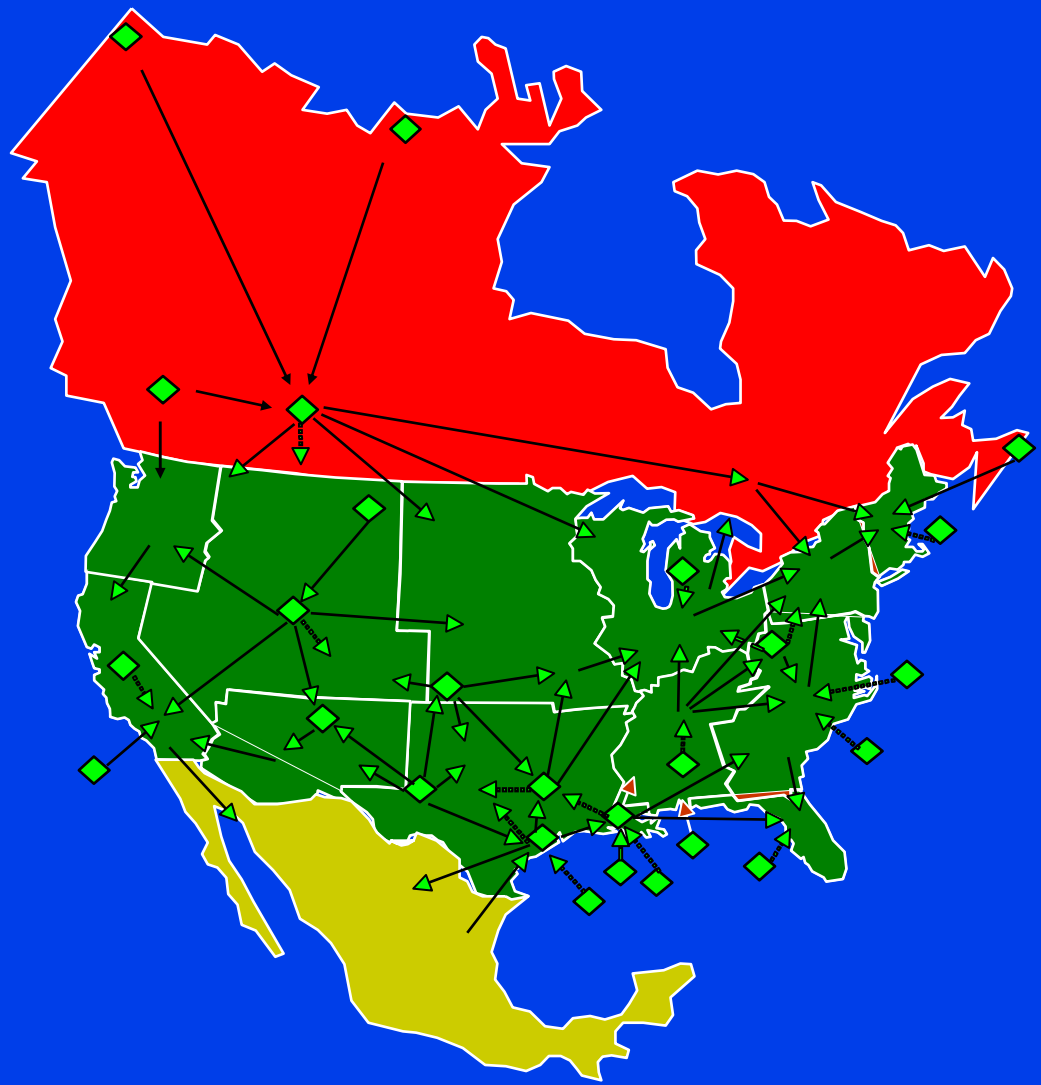
- **Exploration:**
  - Prospects ranked on full cost, expected value basis
  - Exploration activity constrained by infrastructure
  - Discovery process method used
- **Development:**
  - Evaluated on a sunk exploration cost basis, in context of current markets, reservoir depletion stage, and available technology
- **Production:**
  - Future production based on demonstrated reservoir deliverability, regulatory and market constraints, and future operating costs and conditions

Overview of GSAM Downstream Model

- **Downstream Model includes:**
  - Demand models to account for the residential, commercial, industrial, and electrical power sectors
  - Natural gas demand characterization for four seasons in a year
  - Pipeline network including 44 supply/demand nodes and 79 bi-directional links representing the pipeline system
  - Ability to expand pipeline/storage/peaking supply capacities
  - Integrating linear program to balance supply and demand of gas based on the concept of maximizing consumer surplus+producer surplus for each region, year, and season
  - Computation of equilibrium market prices, quantities, and flows subject to network and other constraints
  - Integrating LP contains over 450,000 variables and over 80,000 constraints

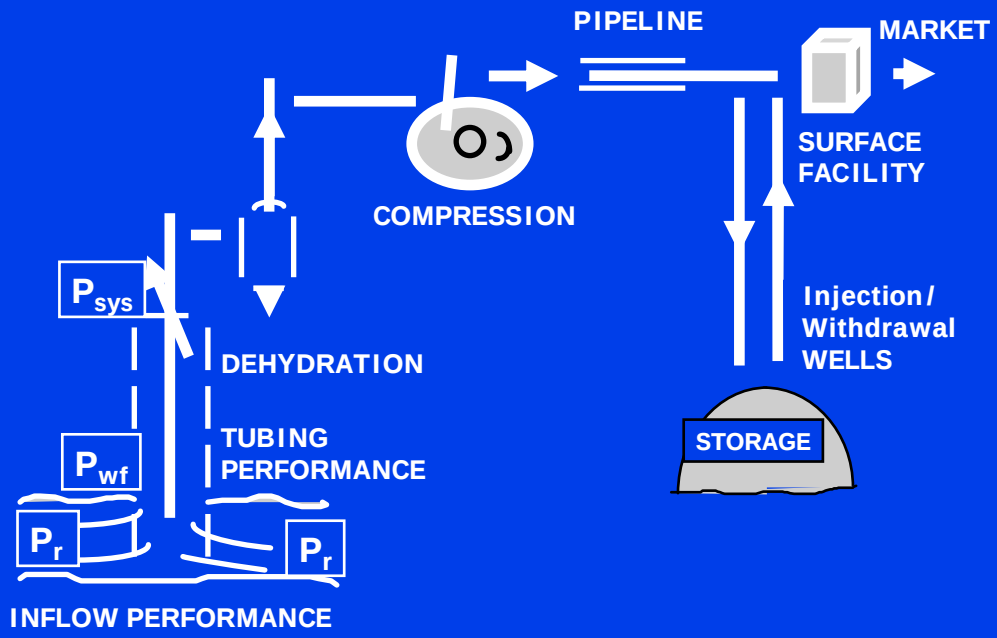
GSAM Transmission Network

- The model has 79 transportation links connecting supply basins and demand regions
- The model internally makes economic decisions to expand pipeline capacity to meet new requirements
- Storage, LNG, propane/air options simultaneously evaluated with pipeline alternatives



Gas Storage Modeling in GSAM

- Applies upstream model processing to 400 existing and "typical" potential storage reservoirs in each region
- Adds gas injection function
- Selects higher deliverability reservoirs per unit of storage cost
- Storage competes with pipeline capacity
- Provides *characterization of overall demand for seasonal storage services* (3 withdrawal and 1 injection season per year) in North America



Ongoing Tasks

- Update GSAM discovered and undiscovered resource database by utilizing the following
  - 14th Update of Significant Oil and Gas Fields of the United States Database, NRG Associates, August 1999
  - Gas Information System (GASIS) Release 2, June 1999
  - Unconventional Natural Gas Resource and Gas Composition Databases, Gas Research Institute, May 1999
  - Earth Science Associates, USGS - Federal/Private Lands Characterization
  - Digital Data Series, USGS, Release 2, 1996

Ongoing Tasks (Continued)

- Update other data in GSAM based recent releases
  - Drilling and Completion Data (API's Joint Association Survey)
  - Operating Cost Data (EIA's Costs and Indices for Domestic Oil and Gas Field Equipment and Production Operations Study)
  - Regional Drilling Capacity Data (Joint Association Survey)
  - Environmental Cost Data (DOE's NPC Study)
- Incorporate American Gas Association (AGA) 1999 release of *"Underground Storage of Natural Gas in the U.S. and Canada"* report in the Storage module of GSAM

Ongoing Tasks (Continued)

- Develop, Test and Calibrate the Industrial Demand Model
- Provide Updated Documentation of User's Guide for the following Modules of GSAM:
  - Reservoir Performance Module
  - Exploration and Production Module
  - Demand and Integrating Module
  - Production Accounting Module
  - Storage Reservoir Performance Module

Future GSAM Enhancements

- Natural Gas Storage/Pipelines
  - *High Deliverability Storage*
    - Salt Caverns
    - Other High Deliverability Storage (Refrigerated Mined Caverns, Lined Rock Caverns, Chilled Mined Gas Storage)
  - *Improved Storage Reservoir Characterization in GSAM*
  - *Storage and Transportation Model*

- Natural Gas Supply to Meet Growing Demand
  - *Federal Lands*
  - *Unconventional Gas (Deep Gas)*
  - *Gas Hydrates*

Future GSAM Enhancements (Continued)

- Climate Change Issues
  - *Electrical Power Sector Characterization of Emissions in GSAM*
  - *Industrial Sector Characterization of Emissions in GSAM*

- General GSAM Improvements
  - *Enhance the existing Graphical User Interface of GSAM*
  - *Speeding up the computation of market equilibrium values*
  - *Speeding up the reservoir performance and exploration production modules*
  - *GSAM^{2000} - The Next Generation Model*

Natural Gas Issues Analyzed Using GSAM

- Marginal Gas Well Study (for BLM)
- Exploration and Production Technology Development (for FETC)
- Impact of Canadian Carbon Stabilization Programs on North American Market (for EPA)
- Natural Gas Metrics (for FETC)
- Deepwater Gulf of Mexico Supply Sub-Module Development for NEMS (for EIA)
- Impact of Environmental Regulatory Initiatives (for DOE/HQ)
- Impact of Tax Incentives/Tax Policy (for DOE/HQ)