Hynomics
(formerly HyBrithms Corporation, formerly Sagent Corporation)

# Technology to Control Hybrid Computer Systems

*Businesses and industries, both large and small, increasingly rely on complex, distributed networks of computers and information systems. Manufacturers, international banking firms, independent physicians in medical networks, utilities, food and commodity distributors, retailers, and communications companies are all examples of industries that could use complex computer networks to manage operations. However, efficient and effective control of distributed systems is difficult, particularly in the increasingly common situation where the system is a "hybrid" that includes discrete and continuous functions and digital and analog signals. A major obstacle has been the need for network and application synchronization-the task of assuring that events between different nodes on the network happen in the proper order and that data managed by different nodes remain consistent.*

*In late 1995, after years of conducting research, Dr. Wolf Kohn and Dr. Anil Nerode founded Sagent Corporation (currently named Hynomics) to turn a breakthrough in theoretical mathematics into technology for hybrid systems, automata (software), and control theory. They sought ATP funding to accelerate their research and development. With cost-sharing from ATP, Dr. Kohn and his team developed Multiple-Agent Hybrid Control Architecture (MAHCA) technology to reactively synchronize real-time distributed processes under uncertainty and continuously maintained system-operating constraints. This technology is being commercialized with SAP, the leading supplier of enterprise management software.*

**COMPOSITE PERFORMANCE SCORE**
(based on a four star rating)
* * *

**Research and data for Status Report 95-09-0052 were collected during January - March 2002.**

## Existing Technology Left Processes Distributed

By the mid-1990s, many distributed processes were deployed in business, government, and industry to implement functionalities of varying complexity. Manufacturing firms were studying "virtual enterprises" that could connect their design and manufacturing operations with their suppliers via computer networks. International banking firms were relying on large-scale networks and resource planning software to coordinate activities among branch offices in the volatile world of international finance.

Complex enterprise resource planning systems are used to manage operations in many businesses and industries, such as medical networks, utilities, food and commodity distributors, retailers, and communications.

In many of these distributed processes, automation extends only to low-level tasks performed by pre-determined procedures. For more high-level coordination and synchronization of tasks, humans must still be a part of the process. These distributed systems relied on extensive manual intervention to achieve the desired enterprise functionality.

## Commercial Need to Increase Optimization and Synchronization of Processes

Efficient and effective control of distributed systems is difficult, particularly in the increasingly common

situation where the system is a "hybrid" that includes discrete and continuous functions as well as digital and analog signals. A major obstacle to controlling these systems has been the need for network and application synchronization; that is, the task of assuring that events between different nodes on the network happen in the proper order and that data managed by different nodes remain consistent.

Industry practice for the integration of heterogeneous systems requires extensive and expensive integration hexperiments and the prototyping of integration alternatives. The addition of new components requires that the experiments be repeated since current approaches depend upon simulation or prototyping experiments to identify failure modes of the composed system. Commercial control, design, and implementation tools have code-generation capability based upon analysis of extensive experimentation of the interaction of logic and continuum constraints. These tools all depend on the assumption that a solution exists for a complex, nonlinear, composed system model.

### Hynomics Seeks to Increase Efficiency of Large-Scale Distributed Systems

Hynomics proposed a new approach to address the problem of network and application synchronization. Their approach included two mechanisms to achieve the next significant increase in efficiency for large-scale, real-time, distributed systems. Hynomics' approach would lower the cost of building and maintaining these systems by providing a flexible framework for automatic compliance with declared constraints in accordance with specified relaxation criteria for achieving a "close-enough" solution.

First, individual agents react to satisfy (synchronize) explicit local and global constraints on system execution. This unified treatment of hybrid system requirements produces a formal methodology that permits effective synchronization of local goals and resulting control strategies with global goals. It also simplifies stating and maintaining distributed system requirements.

Second, a network of agents coordinate to achieve local and global control of distributed processes. This is done via a global cost criteria and by generating software (automata) at each local node and at each update interval (time scale) that comply with logical and continuum (hybrid) constraints on global system behavior. This supports treating either entire blocks of legacy software as components or new small segments of code as components, since agents can be used reactively to seamlessly integrate previously un-integrated, real-time systems.

***A major obstacle to controlling these systems has been the need for network and application synchronization.***

Before the ATP-funded project began, Hynomics' approach was a theoretical construct, and Hynomics had demonstrated the feasibility of this approach only for very small problems. Many barriers still remained to demonstrating that this approach could be turned into a viable technology suitable for industrial application.

### Need for High-Risk Capital Leads Company to ATP

Early revenue from the Army Research Office to develop battlefield dynamic simulation using Hynomics' developing technology and modest angel investments maintained the cash flow and funded the company's small-scale R&D initiatives. Silicon Valley's largest and most influential players were also interested in Hynomics' budding technology. Because there was no demonstrable prototype, however, Hynomics was not able to secure any venture capital.

To launch the high-risk R&D initiative necessary to build the final product, Dr. Kohn turned to ATP. In 1995, Hynomics was granted a two-year, $1.9 million award to 1) decrease the amount of memory required to implement Hynomics' program-generation algorithm, which was initially an exponential function of the complexity of the system being controlled; and 2) build a semantic-based user interface that would lower the technical barrier to enabling users to enter the mixed-mode (i.e., logic and evolution) models accommodated by the technology. There was potential economic advantage to the nation through lower costs of producing and maintaining distributed, real-time systems. Furthermore, this economic advantage had

potential benefits for other industries served by real-time software and hardware.

## Hynomics Uses Middleware Technology to Coordinate Distributed Processes

Hynomics' proposed technology included a distributed agent-based platform for the implementation of management, decision, and control systems (a technology that provides a common interface and translation between two applications, between an application and an operating system, or between other system services). This middleware system is a crucial architecture foundation for second-generation client/server configurations. Second-generation client/server architectures tend to use a distributed function model versus the remote data model common in first-generation client/server applications, wherein a client with a large amount of application logic interacts with a database server.

*Advances made in the technology during the ATP-funded project have enabled Hynomics to commercialize its technology through the world's largest enterprise software companies.*

With the distributed function model, application logic is distributed between client and server on either side of the middleware. The control-services layer in the middle comprises transaction monitors/servers, database gateways, and distributed function servers. Hynomics' technology would enable developers of client/server systems to build intelligent middleware into their applications.

Hynomics successfully completed the development of this technology by incorporating agent technology into the implementation of the middleware.

## Multiple-Agent Hybrid Control Architecture

The key technology breakthrough on this project was Hynomics' development of MAHCA (Multiple-Agent Hybrid Control Architecture), which implemented and extended the theoretical work done on hybrid control prior to the project. MAHCA incorporated earlier theories on agent-based hybrid control and extended the implementation to include agents to analyze, design, and implement intelligent control of large-scale distributed processes. A single agent can be configured to control more complex distributed processes, while multiple agents interact through messages and can be either permanent or temporary.

MAHCA is useful for reactive synchronization of real-time distributed processes that require decision-making under uncertainty, where constraints on system operation must be continuously maintained, and where human operators must be kept informed of current system operation. The architecture also provides support for reuse of existing, trusted components and expanded functionality in components through formal construction of correct real-time software. Finally, MAHCA agents can be used in conventional digital procedures to speed up those procedures and compose more complex procedures.

*The key technology breakthrough on this project was Hynomics' development of Multiple-Agent Hybrid Control Architecture.*

After successful implementation, MAHCA demonstrated the potential to handle large-scale hybrid control problems.

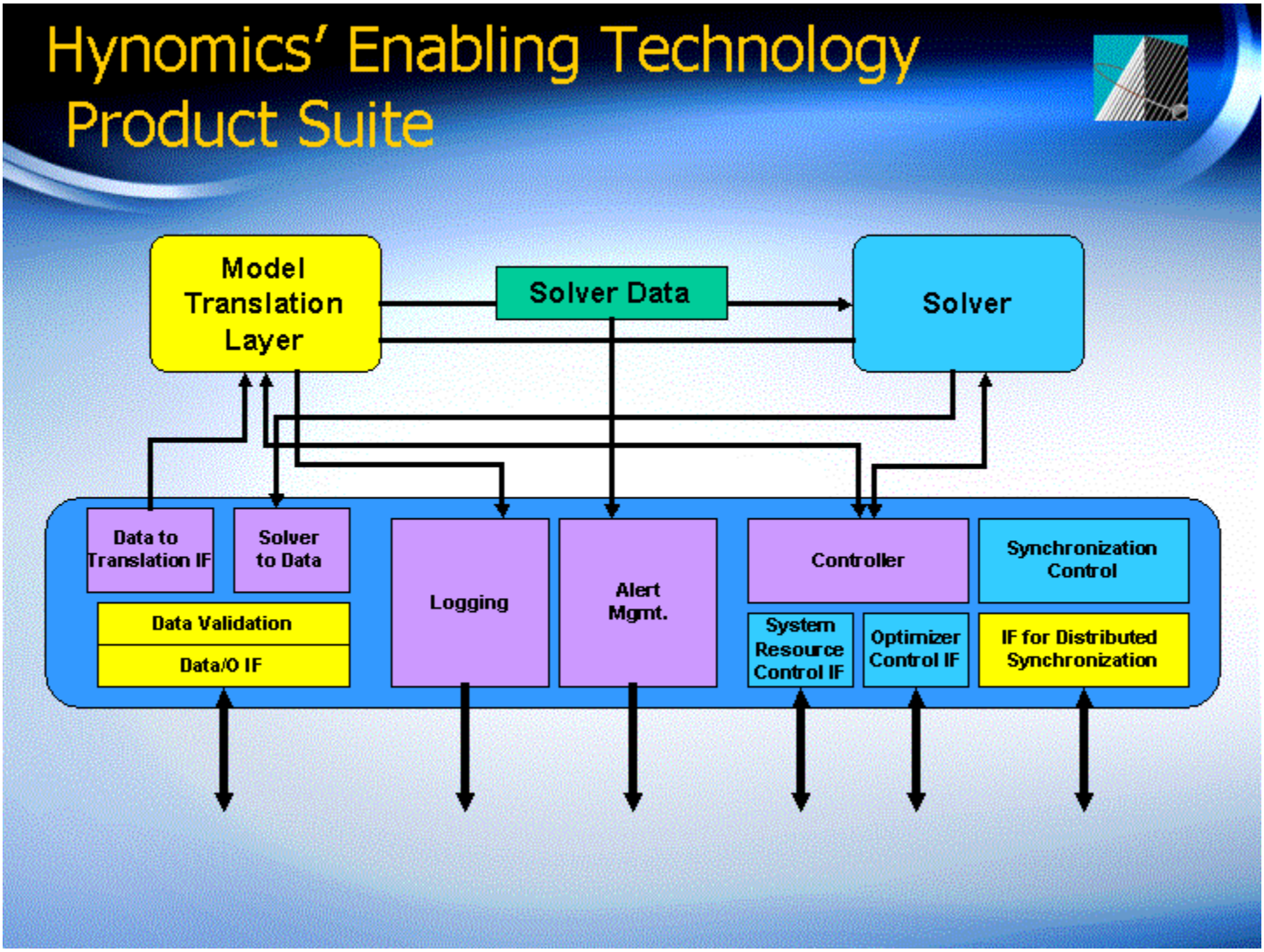
## Partnerships Will Increase Market Access

After the ATP project, Hynomics positioned itself to license to original equipment manufacturers (OEM) for larger systems integration companies. Several years after the project was completed, Hynomics met with various private and venture capital investors and held discussions with several large system integration companies. In 1999, Hynomics formed a partnership with SAP, a global enterprise resource planning software developer, to build a workforce optimizer and a people scheduler. Hynomics continues to build partnerships with enterprise software companies in order to gain access to wider markets without high sales and marketing expenses. Hynomics will continue this model of partnering with large systems integration companies to secure revenue streams, to enter

markets, and to co-invest on future R&D projects. These partnerships will also become the foundation for direct investments into Hynomics. Currently, the company is working on a second significant partnership with one of the world's largest software companies to incorporate its technology into their current and future products. Hynomics has also published more than 15 articles in various professional journals and has participated in over 10 conferences and presentations.

## Conclusion

ATP provided funding to Hynomics to help advance high-risk research in hybrid systems, automata, and control theory through the implementation of its theoretical work in the middleware and MAHCA (Multiple-Agent Hybrid Control Architecture) technologies. This risk was beyond what the private sector was willing to bear. The advances made in the technology during the ATP-funded project have enabled Hynomics to commercialize its technology through the world's largest enterprise software companies. This technology continues to be the apex of Hynomics' solution offerings today. The application of Hynomics' technology with enterprise software players could positively impact optimization and synchronization of companies worldwide.




A flow chart illustrating Hynomic's enabling technology systems.

# PROJECT HIGHLIGHTS
## Hynomics
## (formerly HyBrithms Corporation, formerly Sagent Corporation)

**Project Title:** Technology To Control Hybrid Computer Systems (Cost-Based Generation of Scalable, Reliable, Real-Time Software Components)

**Project:** The primary technical objectives of the project were to 1) decrease the amount of memory required to implement the Hynomics program-generation algorithm that was initially an exponential requirement on the complexity of the system being controlled, and 2) build a semantic-based user interface that will lower the technical barrier to users entering the mixed-mode (i.e., logic and evolution) models accommodated by the technology.

**Duration:** 9/1/1995-12/31/1997
**ATP Number:** 95-09-0052

**Funding (in thousands):**

| | | |
|---|---|---|
| ATP Final Cost | $ 1,934 | 92% |
| Participant Final Cost | 168 | 8% |
| Total | $ 2,102 | |

**Accomplishments:** This project successfully developed new technologies in hybrid systems, automata, and control theory that are in the process of being commercialized. Since the project's completion, Hynomics has formed a multi-layered partnership with SAP and is currently forming another significant partnership with an international software company.

Hynomics has received two patents as a result of the ATP-funded project:

- "Multiple-agent hybrid control architecture for intelligent real-time control of distributed nonlinear processes"
  (No. 6,088,689: filed November 29, 1995, granted July 11, 2000)

- "Multiple-agent hybrid control architecture for intelligent real-time control of distributed nonlinear processes"
  (No. 5,963,447; filed August 22, 1997, granted October 5, 1999)

Hynomics has also published more than 15 articles in various professional journals and has participated in more than 10 conferences and presentations.

**Commercialization Status:** Hynomics is in the process of commercializing a workforce optimizer and a people scheduler with SAP. In 2001, Hynomics raised $280,000 for further R&D. Hynomics continues to partner with large systems integration companies to secure revenue streams, to enter markets, and to co-invest on future R&D projects. These partnerships may also become the foundation for direct investments into Hynomics. Currently, Hynomics is working on a second significant partnership with one of the world's largest software companies to incorporate its technology. Additionally, global software companies and financial services institutions are enthusiastic about the potential for Hynomics' technology to revolutionize supply chain management, transportation and logistics, and portfolio management.

**Outlook:** Hynomics has initiated a promising business plan centered on partnering with OEMs for international enterprise software companies. Initial results of the partnership with SAP are promising, and the budding partnership with a large software vendor could propel this technology and the company forward.

**Composite Performance Score: * * ***

**Number of Employees:** Three employees at project start, 14 as of January 2002.

**Focused Program:** Component-Based Software, 1995

**Company:**
Hynomics
10632 N.E. 37th Circle
Building 23
Kirkland, WA 98033-7921

**Contact:** Dr. Wolf Kohn, CEO
**Phone:** (206) 637-1180

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