# The *da Vinci* Research Interface

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**Abstract**

The *da Vinci*® research interface allows third party developers and research collaborators to retrieve a real-time stream of kinematic and user event data from the *da Vinci*® Surgical System during clinical use. This data includes the motion of all master and slave manipulators, as well as a number of user console events such as button and pedal activations. This paper provides a brief outline of the technical scope of the da Vinci research interface, as well as some discussion of the criteria for accessing this interface, and requirements for establishing a research partnership with Intuitive Surgical Inc.



## Contents

## 1 Introduction

The *da Vinci*® Surgical System integrates 3D endoscopy and state-of-the-art robotic technology to virtually extend the surgeon's eyes and hands into the surgical field, thus enhancing minimally-invasive access for complex surgical procedures [3].

The *da Vinci* Surgical System consists of an ergonomically designed surgeon's console, a patient-side cart with four interactive robotic arms, a high-performance stereo vision system and proprietary EndoWrist Instruments. The surgeon's hand movements are scaled, filtered and seamlessly translated into precise movements of the EndoWrist Instruments. The net result: an intuitive interface with breakthrough surgical capabilities.

In order to support research and further development of the *da Vinci* platform, we offer a research interface—also known as the da Vinci Application Programming Interface (API)—that allows third party developers and research collaborators to retrieve a real-time stream of kinematic and user event data from the *da Vinci* during clinical use. This data includes the motion of all master and slave manipulators, as well as a number of user events such as button and pedal activations. This data is streamed from a TCP/IP Ethernet server embedded within the robotic system, to an external research workstation. Figure 1 illustrates the main system components, including the Patient-Side Manipulators used to position the EndoWrist instruments and stereo endoscope, and the Surgeon Console that includes a stereo display and master controls used by the surgeon to maneuver the Patient-Side Manipulators.

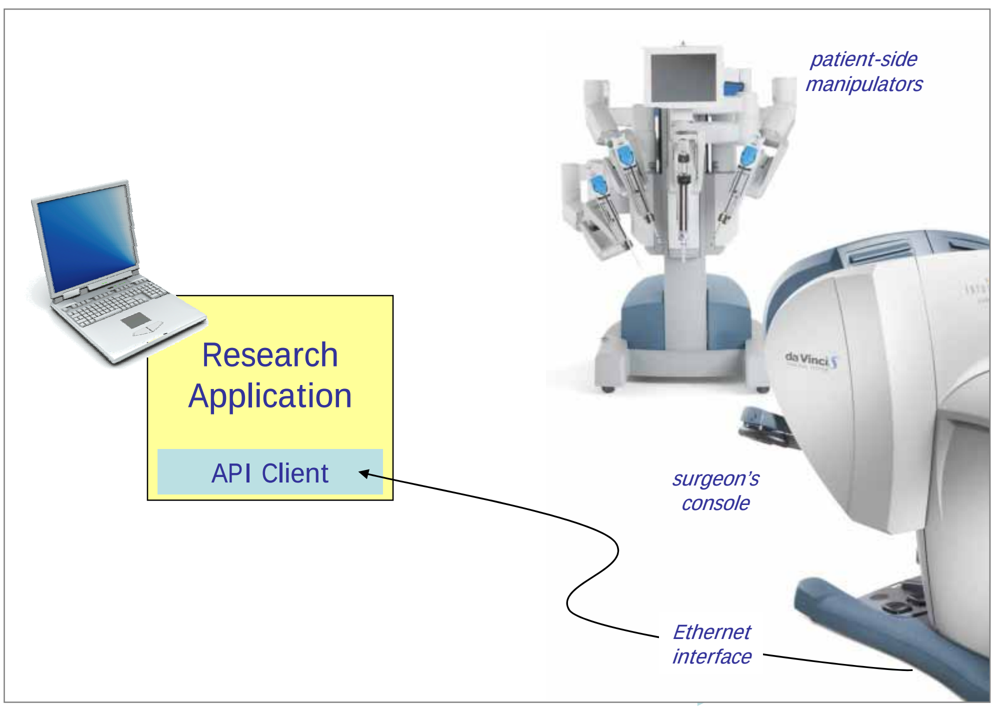


Figure 1: The *da Vinci* research interface—also known as the *da Vinci API*.

This paper provides a brief technical overview of the research interface architecture and the contents of the real-time data stream. Our research partnership strategy and criteria by which access is granted to the *da Vinci* API are discussed in Section 3. Section 4 outlines plans for future support and development of the research interface, while at the end of the paper we provide references to several research papers that describe work that has leveraged the *da Vinci* research interface.

## 2 Technical Overview

The *da Vinci* research interface is based on a TCP/IP client-server architecture, with the server residing on the *da Vinci* System and the client residing on the developer's research workstation. Communication between the server and client is facilitated by a standard Ethernet link. For obvious safety reasons, the API interface is strictly a read-only interface, meaning that kinematic information may only be read from the *da Vinci*, while the ability to effect master or slave manipulator motion—or other system state changes—is not provided by the API interface. Control commands are sent from the client to the server in order to configure, start, and stop the the data streams. This section describes the contents of the API data stream. Note that this description is intended to provide an outline of the data content, rather than a detailed technical reference.

### 2.1 The Data Stream

The API data stream contains kinematic information for each of the *Patient-Side Manipulators* (PSMs), the *Endoscope Control Manipulator* (ECM), and the two *Master Manipulators* (MTMs). This information is sampled at a rate specified by the API client application (10-100Hz) and is transmitted synchronously. The data stream includes the following data fields for each PSM and ECM:

**Set-up Joint Values:** each patient-side manipulator and endoscope control manipulator is supported and positioned by a passive serial mechanism called a "set-up arm". The angles and displacements of rotary and prismatic joints that constitute this arm are contained in this data field.

**Manipulator Joint Values:** the angles and displacements of the manipulator's active joints.

**Manipulator Joint Velocities:** the translational or angular velocity of each active joint.

**Manipulator Remote Center Position:** the Cartesian position and orientation of the manipulator's remote center, which is determined by the pose of the manipulator's set-up arm.

**Instrument Tip Pose:** the Cartesian position and orientation of the tip of the instrument attached to the manipulator. In the case of the ECM, this is the tip of the endoscope.

**Instrument Tip Velocity:** the translational and rotational velocity of the instrument tip.

Kinematic information for the *Master Manipulators*, which are attached to the Surgeon Console (see Figure 1), and manipulated by the surgeon, is also included in the API data stream. The following fields are included:

**Manipulator Joint Angles:** the angles of the MTM joints.

**Manipulator Joint Velocities:** the angular velocity of each active joint.

**End-effector Pose:** the Cartesian position and orientation of the MTM end-effector.

**End-effector Velocity:** the translational and rotational velocity of the MTM end-effector.

### 2.2 User Interface Events

In addition to the synchronous stream of kinematic information, the API interface also transmits a variety of events, triggered by user actions at the Surgeon's Console. These events include the following:

**Head sensor trigger:** the console detects the presence of the surgeon's head when he/she is looking through the display eyepiece. *Head In* and *Head Out* events are triggered and transmitted by the API server.

***Standby* button pressed/released:** the user has pressed/released the *Standby* button on the console.

***Ready* button pressed/released:** the user has pressed/released the *Ready* button on the console.

**Master clutch pedal pressed/released:** the user has pressed/released the *Master Clutch* pedal on the console, thus decoupling the master inputs from the slave manipulators in order to re-position the master inputs within the console workspace.

**Camera control pedal pressed/released:** the user has pressed/released the *Camera Control* pedal on the console, in order to begin maneuvering the endoscope.

**Manipulator arm swap:** on *da Vinci* systems with three PSMs, the user may trigger an "arm swap"—this facilitates control of three PSMs using just two master inputs.

### 2.3 Documentation and Support

Upon establishing an API Agreement with Intuitive Surgical Inc. (see Section 3.1), a research partner will receive an *API Starter Kit* that includes the following:

**API Introduction:** a document containing a definition of the API, installation instructions, and a list of Frequently Asked Questions.

**da Vinci Kinematics:** a description of the kinematics of the patient side of the system.

**Sample Windows application:** source code that demonstrates a simple API client for capturing data from the system. This source code may be compiled using Microsoft Visual C++ 6.0 in order to run under the Windows operating system.

**Sample Linux application:** source code that demonstrates a simple API client implemented for the Linux operating system.

**API Reference Guide:** a reference guide and top-level documentation for the API example client and its source code, covering both Windows and Linux versions.

**Matlab sample code:** that demonstrates the computation of forward kinematics, using our standard representation of the system's Denavit Hartenberg parameters.

# 3 Research Partnership Strategy

## 3.1 The API Agreement

The *da Vinci* research interface provides a rich source of information regarding the set-up and performance of the surgical system, as well as surgeon performance. Therefore, access to the API interface is available to authorized researcher partners only, pending the execution of an API Agreement—a legal document that outlines terms of use, restrictions of use, confidentiality, limitations of liability, as well as agreed rights to intellectual property developed through the use of the *da Vinci* research interface, or data captured from this interface.

The API interface is not active by default and must be activated on-site by a trained Intuitive Surgical Field Engineer—subject to approval of the API agreement. Once the interface is installed and enabled, the daVinci Surgical System may be commanded to serve API data from its Ethernet interface.

## 3.2 Research Collaboration

We have developed four criteria for initiating a *da Vinci API Agreement*, namely:

**Research match:** the proposed research addresses a long-range challenge and complements research and development efforts internal to Intuitive Surgical. A "long-range challenge" is one that is not likely to become obsolete within—or soon after—the proposed project period.

**Technical strength:** a demonstrated track record of research performance and technical expertise, coupled with a strong research plan.

**Clinical strength:** active clinical practice and strong utilization of the da Vinci system that is to be used for research work.

**Communication:** a history of effective communication and collaboration between research personnel and clinical staff.

Experience has taught us that weakness in any of one these four criteria indicates a poor probability of achieving a successful collaboration. It is in Intuitive Surgical's best interests to participate in research partnerships that exhibit a favorable probability of success, in order to effectively utilize limited resources and field support.

In order to establish the strength of the proposed research, we ask that applicants provide a *Statement of Work* prior to the preparation of an API Agreement.

Several research papers that cite the use of the *da Vinci* API are referenced at the end of this paper [1, 2, 4, 5, 6, 7, 8, 9, 10].

# 4 Future Development

The *da Vinci* API is an important research tool and a valuable conduit for surgical data capture; therefore, we aim to continue to support and to expand this feature in the future. Intuitive Surgical is currently collaborating in the development of the *Surgical Assistant Workstation* (described below), an initiative that will further enable researchers to interface with the *da Vinci* system.

## 4.1 The Surgical Assistant Workstation

The Surgical Assistant Workstation (SAW) is a software development framework that is intended to support rapid prototyping of telesurgical research systems. It is currently being developed by Johns Hopkins University researchers within the NSF Engineering Research Center for Computer-Integrated Surgical Systems and Technology, and will be released as an open-source project in the near future.

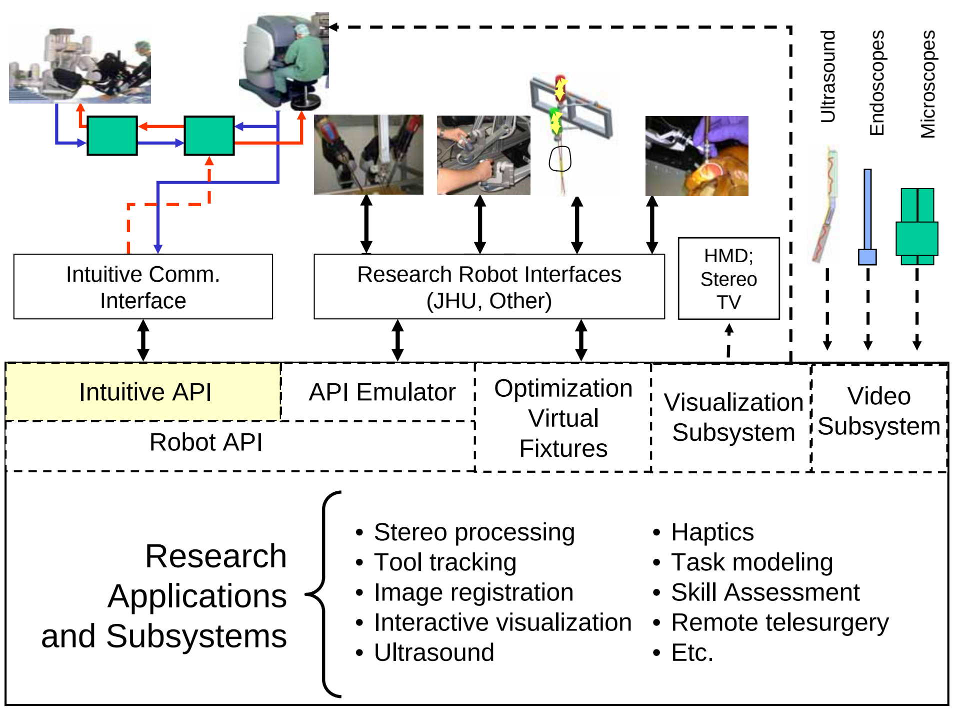


Figure 2: The Surgical Assistant Workstation concept. Image provided by the NSF Engineering Research Center for Computer-Integrated Surgical Systems and Technology.

This framework includes a library of components that can be used to implement master-slave or collaborative robot control systems, with support for complex video pipelines and a novel interactive surgical visualization environment. This library is intended to be easily extensible, such that developers can add support for their own robotic devices and associated hardware platforms.

The SAW application development framework is modular by design, such that it can be used to implement different physical architectures and applications, as illustrated in Figure 2. It provides the main application context and event loops, as well as inter-task communication mechanisms for interconnecting modules and devices with the application logic. A generic API is used to interface with robotic manipulators, while extensive support is provided for implementing video pipelines. A novel interactive user interface mechanism supports the development of interactive 3D surgical environments.

*da Vinci* support will be included as a plug-in to the SAW framework, thus providing a powerful means of developing new research applications using this established surgical platform. The SAW robot API will include support for the *da Vinci* research interface. In addition, the SAW user interface library will include the ability to render interactive graphical overlays for display in the *da Vinci* console. Drivers and plug-ins for the SAW will be available to our research partners, as part of the API Agreement described in Section 3.1.

It is our hope that this software development framework will help our research partners to better interface with the *da Vinci*, while providing a common platform for exchanging technologies and prototype applications in the future.

## References


[1] L. Adhami and E. Coste-Manière. A Versatile System for Computer Integrated Mini-invasive Robotic Surgery. *Medical Image Computing and Computer-Assisted Intervention–MICCAI*, pages 272–281, 2002. 3.2

[2] E. Coste-Manière, L. Adhami, R. Severac-Bastide, A. Lobontiu, J.K. Salisbury Jr, J.D. Boissonnat, N. Swarup, G. Guthart, E. Mousseaux, and A. Carpentier. Optimized Port Placement for the Totally Endoscopic Coronary Artery Bypass Grafting using the da Vinci Robotic System. *Lecture Notes in Control and Information Sciences—Experimental Robotics VII*, 271/2001:199–209, 2001. 3.2

[3] GS Guthart and JK Salisbury. The Intuitive$^{TM}$ telesurgery system: Overview and application. *Proc. IEEE International Conference on Robots and Automation*, 1:618–621, 2000. 1

[4] JD Hernandez, SD Bann, Y. Munz, K. Moorthy, V. Datta, S. Martin, A. Dosis, F. Bello, A. Darzi, and T. Rockall. Qualitative and quantitative analysis of the learning curve of a simulated surgical task on the da Vinci system. *Surgical Endoscopy*, 18(3):372–378, 2004. 3.2

[5] D.M. Kwartowitz, S.D. Herrell, and R.L. Galloway. Update: Toward image-guided robotic surgery: determining the intrinsic accuracy of the daVinci-S robot. *International Journal of Computer Assisted Radiology and Surgery*, 1(5):301–304, 2007. 3.2

[6] J. Leven, D. Burschka, R. Kumar, G. Zhang, S. Blumenkranz, X.D. Dai, M. Awad, G.D. Hager, M. Marohn, M. Choti, C.J. Hasser, and Taylor R.H. Davinci canvas: A telerobotic surgical system with integrated, robot-assisted, laparoscopic ultrasound capability. *Proceedings of Medical Image Computing and Computer Assisted Intervention, Lecture Notes in Computer Science*, 3749:811–818, 2005. 3.2

[7] H.C. Lin, I. Shafran, T.E. Murphy, A.M. Okamura, D.D. Yuh, and G.D. Hager. Automatic Detection and Segmentation of Robot-Assisted Surgical Motions. *Proc. Of Eighth International Conference on Medical Image Computing and Computer Assisted Intervention*, pages 802–810, 2005. 3.2

[8] K. Moorthy, Y. Munz, A. Dosis, J. Hernandez, S. Martin, F. Bello, T. Rockall, and A. Darzi. Dexterity enhancement with robotic surgery. *Surgical Endoscopy*, 18(5):790–795, 2004. 3.2

[9] D. Oleynikov, B. Solomon, and S. Hallbeck. Effect of Visual Feedback on Surgical Performance Using the da Vinci® Surgical System. *Journal of Laparoendoscopic and Advanced Surgical Techniques*, 16(5):503–508, 2006. 3.2

[10] DA Wang, F. Bello, and A. Darzi. Augmented reality provision in robotically assisted minimally invasive surgery. *Computer Assisted Radiology and Surgery*, 1268:527–532, 2004. 3.2