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NONDESTRUCTIVE TESTING OF THE SHROUD OF TURIN: PROJECT STURP

Eric J. Jumper, Robert W. Mottern, John P. Jackson

Introduction

If one were to sit down and try to put together a team of scientists to perform a comprehensive battery of tests on the revered Shroud of Turin, and if one were given no restraints as to time or money then perhaps the group would approach the level of expertise and competence of the Shroud of Turin Research Project (STURP).[1] STURP, however, has not and had not a vast supply of money or time, in fact, in 1976 it had only $100.00 provided to it by the Holy Shroud Guild in America and only dreams that testing would one day be performed.

In this paper, we will attempt to briefly describe the origins of STURP; its organizational structure and personnel; the research goals, testing procedures, and data reduction operations; and some of the special problems including equipment and liaison which had to be overcome.

Historical Background

STURP is really the fruition of a process which started 82 years ago with the famous photographs of Secundo Pia, continuing through the scientific commission of Yves deLage, the outstanding contribution of Dr. Pierre Barbet, the work of such people as G. Judica-Cordiglia and the work of the International Center of Sindinology (whose success over recent years is in no small part due to Don Piero Coero-Borga). But the process had its most recent progress because of Cardinal Pellegrino's giant step in 1969

Enrie says: This should be Tino Zeuli But it was Judica-Cordiglia

and again in 1973 of granting permission for a team of experts to directly examine the Shroud. This effort was sponsored by the International Center of Sindinology with Dr. Prof. Pier Luigi Baima Bollone playing a large role as overseer and coordinator. We will return to this event and its significance.

While all this progress was taking place in Europe, the United States played the role of interested observer. Sometime in 1933, while a student in Rome, Fr. William T. Barry, CSSR visited Turin and received from G. Enrie a set of 3 x 4 inch glass latern slides and brought them back to the United States. The interest from these slides and an article "I Saw the Shroud" by Fr. Peter Rinaldi, S.D.B. formed the basis for what today is the Holy Shroud Guild in America.[2] The Guild's charter was to make available to America information about the Shroud and promote scientific research on the cloth. It was in the early days that the Guild was instrumental in the publishing of Dr. Paul Vignon and Edward A. Wuenschel's article in Scientific American.[3]

The Guild's main function was to provide information and this they were most successful in doing. Research using only the Enrie photographs also took form[4] but despite great enthusiasm nurtured in such places as the FBI crime lab by the efforts of Fr. Adam Otterbien among others, physical science investigations were never fruitful; the time was not right, access to the Shroud was to wait for later times.

In about 1972 a new Ph.D., Dr. John P. Jackson (Physicist) began correspondence with the Guild with an idea to do indirect physical science investigations on the Shroud using computer image enhancement techniques created by the new science of image enhancement which had grown from the United States space program. His idea for new research was brought to fruition by his association in early 1974 with Donald Devan, a scientist working in the image enhancement field. Little did Jackson and Devan realize that this fortuitous association would grow into the Shroud of Turin Research Project.

At approximately the same time as this meeting Jean Lorre and Donald Lynn of the Jet Propulsion Laboratory were introduced to the Shroud by Thomas Dolle and encouraged to apply image enhancement techniques to Shroud photographs. In 1976, through communication provided by the Guild, Jackson and Dr. Eric J. Jumper (Mechanical Engineer/Laser Physicist, who had aligned with Jackson and Devan in the summer of 1974) learned of the work of Lorre and Lynn. By this time Dr. Ray Rogers, Dr. Robert Dinegar, Don Janney and Roger Morris (all from Los Alamos Scientific Laboratory) and Robert Mottern (from Sandia Laboratory) had all become interested in further physical science studies on the Shroud of Turin.

In late 1976 the structure of STURP began to take form with Jackson and Jumper acting as prime coordinators and communication hubs. Their decision to call a United States Conference on the Shroud turned out to be the first formal step in the creation of STURP.

Organizational Structure

The 1977 United States Conference of Research on the Shroud of Turin brought together not only those mentioned previously, but also Dr. Joseph Gambesia MD, Dr. Robert Bucklin MD, Capt Joseph Accetta (US Air Force), Maj Rudolph Dichtl (US Air Force), and Dr. Walter McCrone (McCrone and

Associates) among others. The first day of the meeting was devoted to a presentation of papers on past and ongoing research as well as techniques which would be useful should direct testing of the Shroud take place.[5] On the second day a workshop was held to outline a set of nondestructive tests the group would like to see done and were prepared to perform should permission to do testing be given.[6] From the discussion in the workshop, a 17 page proposal for testing was developed[7] delineating specific tests to be performed and key personnel who would be in charge of performing said tests.

Why this kind of effort? We have mentioned earlier the testing of the 1969 and 1973 commission; this set a new precedent direct testing of the Shroud had actually taken place. Fr. Rinaldi, Vice-President of the Holy Shroud Guild who was also present at the meeting, brought news from Turin that the International Center was pushing for an exposition of the Shroud in 1978, the 400th year of its stay in Turin, and, most importantly to us, the center hoped to be able to add new testing as one of the events of the Exposition.

In September of 1977, a group of eight people representing the 1977 United States Conference and consisting of Jackson, Jumper, Accetta, Morris, Devan, Mottern, Otterbein, and Kenneth Stevenson (joining the group after the 1977 conference as technical editor and recording secretary) traveled to Turin and presented the proposal to representatives of the International Center who later passed the proposal on to The New Archbishop Ballestrero.

In April of 1978 our group received word that permission to perform at least some of the tests we proposed would be granted. In June 1978 a workshop was held in Colorado Springs, CO, to begin the monumental task which faced us of preparing to go to Turin and test the Shroud. New members joined the team as required by the planned tests and the task of assembling, constructing and shipping the huge amount of equipment we needed. Among these were Thomas D'Muhala and George Markoski (NUTEK Corporation), Dee German (US Air Force), Ron London (Los Alamos Scientific Laboratory), Vernon Miller, Ernie Brooks, and Mark Evans (Brooks Institute), Barry Schwortz (Barry Schwortz Photography), Charles Webb (Kodak) and Roger Gilbert (Oriel Corporation).

At this point STURP had no money and only a small fraction of the equipment at it's disposal. Thanks to contributions by many companies and individuals, equipment was designed, constructed, leased and purchased, and assembled in Amston, Connecticut. In early September the team assembled in Amston for a dry run and equipment shake-down. Among equipment that had to be specially built was a visible/ultraviolet spectrometer (two kinds constructed), a frame for camera equipment to be stationed in front of the Shroud and a large frame for holding the Shroud during the testing. During the September dry run, test plans were finalized and Shroud-test locations picked. From this a 63 page operations test plan was put together and printed laying out a detailed 96 hour test plan complete with contingency plans, test locations and test philosophy.[8]

At this same time a non-profit corporation took form spearheaded by the business know how of Tom D'Muhala and George Markoski. Papers were prepared and submitted to the United States Internal Revenue Service and filed in the State of Connecticut. Fund raising efforts were in full swing.

Figure 1 shows the organizational structure of STURP[9] at the time of the testing in October of 1978 including added members necessary for data reduction in some cases added after October of 1978.

After the dry run equipment was crated and shipped to Turin for the testing in October 1978.

<u>Scientific Aspects of the Project</u>

The goals of our research are to determine the chemistry and character of the cloth and image(s) on the Shroud. From these we hoped to address the question of authenticity and image formation process(es). To achieve these goals six major tests were performed. These were x-ray fluorescence, chemical analysis, photography, infrared, radiography and visible and ultraviolet spectroscopy.

A special test fixture was constructed to support the fragile 4.4 meter by 1.1 meter fabric of the Shroud and its protective backing cloth. The cloth was spread out on the horizontal frame and secured along the edges with magnets. The frame was rotated to a vertical position for the tests. Panels, 20 cm wide and extending the width of the frame, were removed singly for some tests, such as, radiography and x-ray fluorescence.

STURP

- Coordinators
  - John P. Jackson
  - Eric J. Jumper
- Photographic
  - Team Chief: Don Devan
  - Documentation: Barrie Schwortz, Ernie Brooks
  - Scientific Photography: Vernon Miller, Mark Evans, Jean Lorre, Don Lynn, Don Janney
- Chemical Analysis
  - Team Chief: Raymond Rogers
  - Visible Microscopy: Walter McCrone
  - Chemistry-Analytic: Robert Dinegar, Diane Soran, John Heller, Joan Janney
- Infrared
  - Team Chief: Joe Accetta
  - Thermography-Spectroscopy: Steve Baumgart
  - Thermography: Thomas Haverty
- Vis/UV Spectroscopy
  - Team Chief: Roger Gilbert
  - Spectroscopy: Samual Pellicori, Marian Gilbert
- X-Ray Fluorescence
  - Team Chief: Roger Morris
  - Ron London, Larry Schwalbe
- X-Ray Radiography
  - Team Chief: Robert Mottern
  - Herb Sisson
- Advisors
  - Liaison: Fr. A. Otterbein
  - Medical: Robert Bucklin, J. Gambesia
  - Public Affairs: Kenneth Stevenson
  - Powders: Govanni Riggi
  - Business: George Markoski
- Logistics
  - Team Chief: Thomas D'Muhala
  - Electronics: Dee German, Patsy German, Rudolf Dichtl, Joan Dichtl
  - Support: Thomas Dolle, Marjorie Jumper, Kay Jackson, Mary Stevenson
- Computational Support
  - Bob Ewing, David Bowman

Figure 1. Organization of Shroud of Turin Research Project

X-ray Fluorescence

The x-ray source used for radiography was used to excite a foil of tin. A lead collimator was installed over the end of the x-ray tube (Figure 2). The tube was located so that a 50 kVp x-ray beam would impinge upon the tin. The 25.5 keV K-alpha was filtered by a silver foil at the exit end of the collimator. A Si(Li) detector was mounted coaxially above the x-ray source. A lead shield with a 4 mm collimation hole was fitted over the detector. This arrangement defined a one square centimeter sample area on the cloth.

The combination of x-ray source and detector was mounted on a heavy duty camera tripod. It could, thus, be raised and lowered across the width of the cloth. Also, the arrangement could be rotated for background and calibration measurements.

Pulses from the detector were fed to a linear amplifier and stored in a 512 channel pulse height analyzer. After a 2000 second counting interval, the accumulated spectrum was stored on a digital tape cassette for subsequent analysis.

Titanium and copper foils were used for calibration. From the measured positions of the K-fluorescence lines of these standards and their tabulated energy values a calibration curve was determined. Calibration data were collected before and after each test data run.

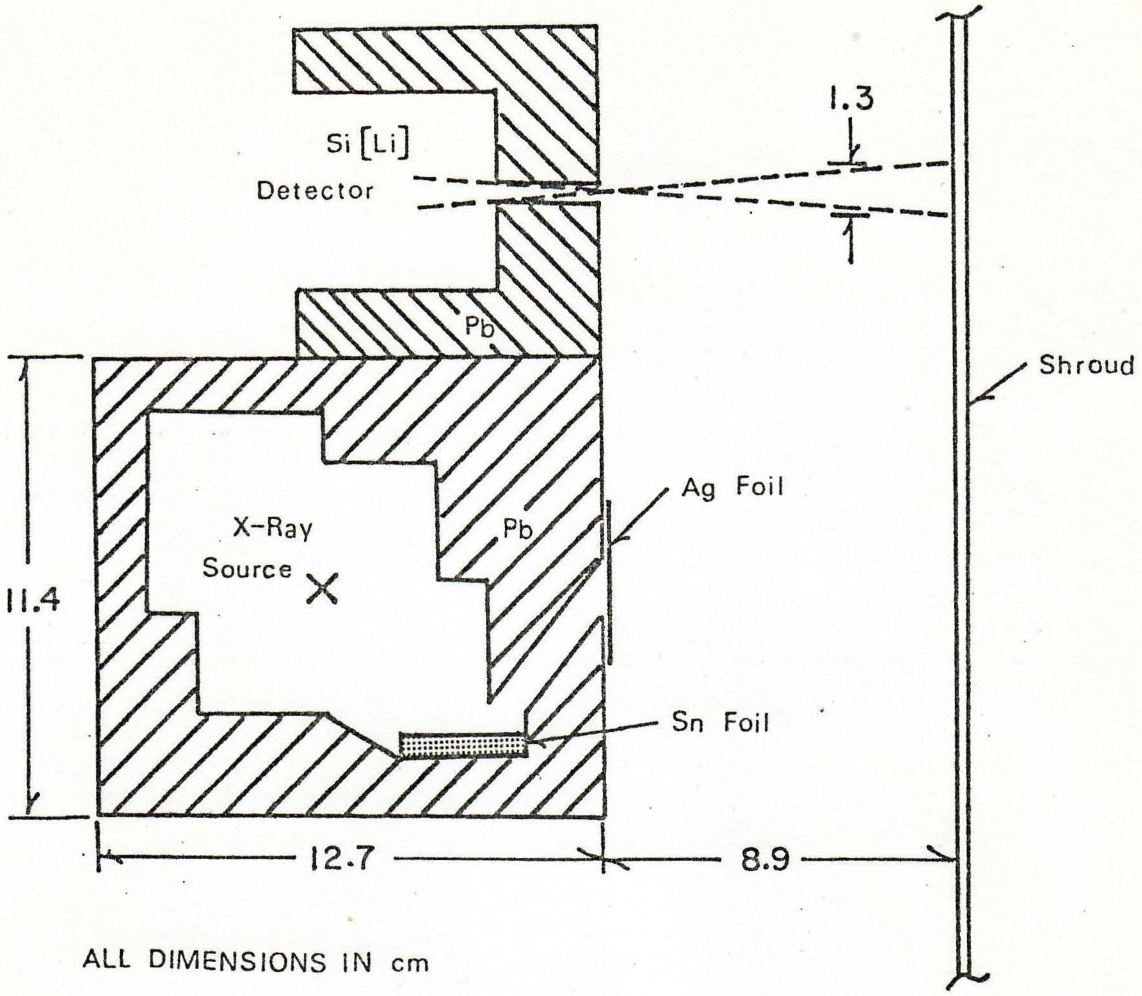

Figure 2. X-Ray Source and Detector Shielding and Collimation

Chemical Analysis

Trace samples of surface materials were obtained by means of adhesive tape. The tape and the adhesive were compounded of pure hydrocarbon. A specially designed roller was used to apply the adhesive to selected areas of the linen cloth. After being carefully removed the tapes were attached, with the adhesive side up, to microscope slides and identified. Spectral photometric measurements were made on each sample area before and after application of the adhesive. All slides were stored in a plastic box which was tightly sealed.

The tapes are being examined by microscope and analyzed by the micro Raman method. Additional analysis will be performed by electron spin resonance, electron spectroscopy, ion microprobe and scanning electron microscope.

Photography

Mosaics at 5.6:1 and 22:1 reduction were made of the entire surface of the cloth. For each section a successive series of exposures were made with red, green and blue filters for color separation. In another series ultraviolet transmission filters were used for contrast enhancement. To detect fluorescence in a different series, ultraviolet transmission filters were used over the light sources while ultraviolet blocking filters were used over the camera lens. For another series the visible spectrum was partitioned into 100 Angstrom intervals by a series of filters.

Specific areas of interest were photographed at approximately 3:1 enlargement. Other areas were photographed through a microscope with 3x to 50x zoom capability and a 35 mm camera attachment.

Infrared

Infrared sensitive film was used to photograph the images and stains on the cloth. By placing filters over both the light sources and camera lens photographs were made in the near-infrared region.

Reflectance measurements, as a function of wavelength, were made in the ranges of 3 to 5 microns and 8 to 14 microns.

The integrated emissivity in the ranges of 3 to 5 and 8 to 14 microns were recorded by a thermographic camera. The cloth was illuminated by unfiltered tungsten light. The thermographic images were recorded on Polaroid film for later analysis.

Radiography

Low energy radiography was performed at 15 kVp. The x-ray source with a 1.5 mm square focal spot was positioned on a heavy duty tripod 1 meter from the linen cloth. A 20 cm wide panel was removed from the frame on the side opposite the source. A 36 cm x 43 cm film pack, containing a type DR and type M film, was taped over the opening. Following the exposure and removal of the film pack the source was moved vertically one-quarter the width of the cloth (approximately 27.5 cm). Another two film pack was taped over the opening in line with the source and exposed. After the third relocation of the x-ray source and exposure the panel was re-installed and an adjacent panel removed. The tripod with the x-ray source was aligned with the new opening and three more exposures made. In this manner the entire subject was radiographed.

An aluminium frame, approximately 1.25 m by 1.5 m, was suspended on the source side of the cloth. The frame was strung with horizontal and vertical wires spaced 20 cms apart. Each intersection of wires was identified with a unique letter-number pair. Thus, each radiograph was identified by shadows of wires and their intersection identifiers.

A darkroom was set up in a nearby room. All films were manually processed shortly after exposure. In another room film viewers were located and the processed films were given a preliminary examination. Any needed correction in exposure was relayed to the test room.

Visible and Ultraviolet Spectroscopy

A special reflectometer (Figure 3) was constructed. It was used interchangeably for reflectivity and fluorescence measurements.

For the reflectivity measurements the broad band radiation from a xenon arc lamp was directed through a source monochromator. The beam from the monochromator was imaged on a 6 mm by 3 mm area. Reflectivity scans were made from 250 to 750 nanometers. From 420 to 750 nanometers a long pass filter was inserted before the detector monochromator. The band width of the monochromator was 5 nanometers. Magnesium oxide was used as a reference for the reflectivity scans.

For the fluorescence measurements the light source used was a mercury arc lamp. The source monochromator was fixed at 365 nanometers. An ultraviolet transmission filter was inserted after the source monochromator and another which blocked ultraviolet and transmitted visible light was inserted before the detector monochromator. The detector monochromator was scanned from 390 to 700 nanometers. The band width was 8 nanometers for the fluorescence measurements.

Reflectivity and fluorescence scans were also made on sample cloths from the Egyptian Museum in Turin. In addition scans were made on filter papers which had been scorched and smeared with various paint pigments.

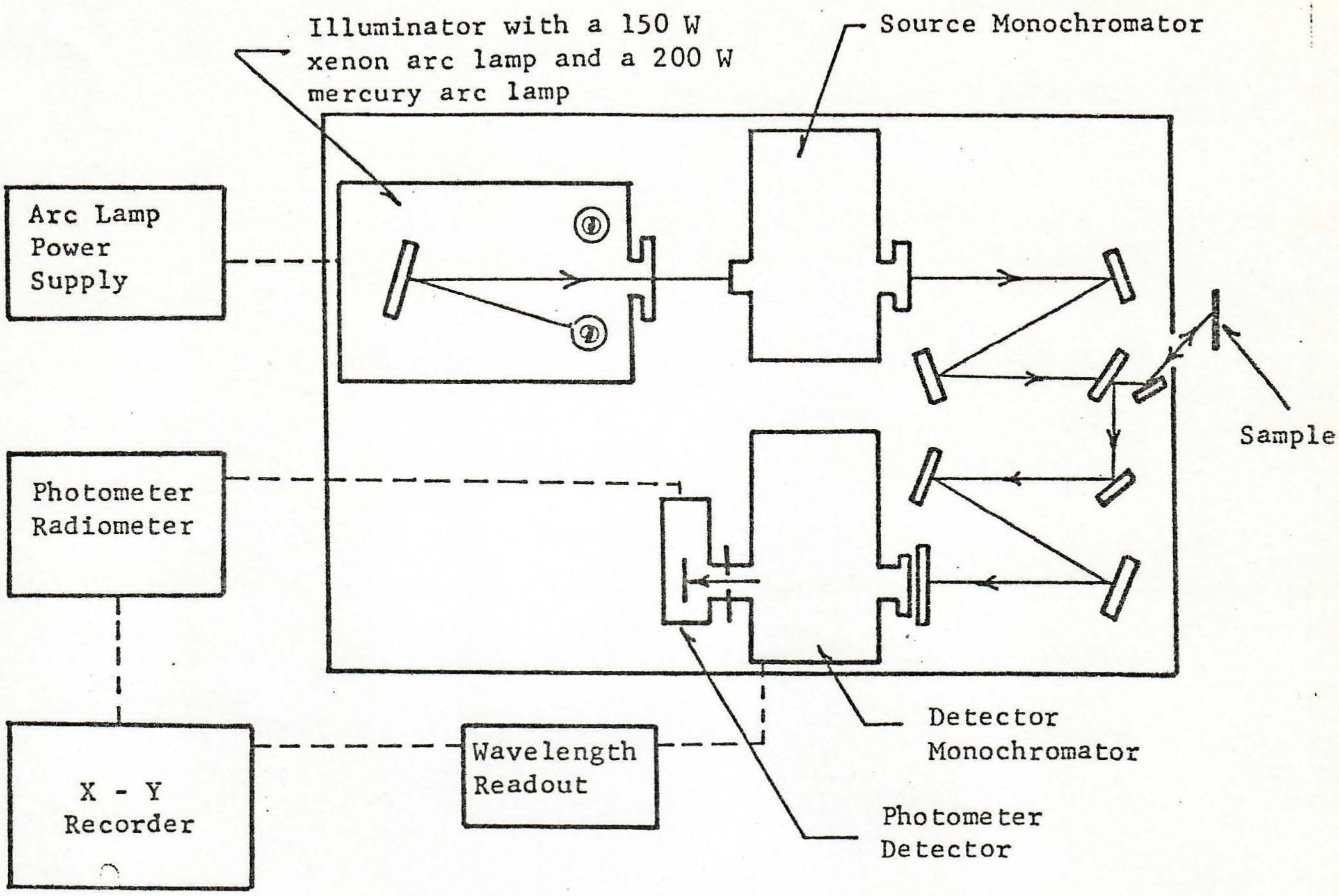

Figure 3. Block Diagram of Reflectometer/Fluorimeter

In addition a second portable reflectometer was constructed for corroberative and backup spectrographic analysis. It was a continuously variable interference filter wheel to resolve a 17 nm full width at half max band, and a silicon photodiode detector. Points 20 nm apart were recorded. A 1 cm diameter field at 50 cm distance was viewed. Readout was with liquid crystal digital display. A 500 W tungsten lamp illuminated the Shroud, and a MgO surface was used as a reference. Six samples of each type stain and clear background were measured, some repeatedly.[10]

Additional tests not noted here were performed on an opportunity basis which included transmission photographs, side lit photographs and glancing photographs.

Data Reduction and Information Release

Since the team returned in October of 1978 data reduction and interpretation has been underway. Two data reduction meetings have been held one in March of 1979 in Santa Barbara, California, and one in October 1979 in Los Alamos, NM. In addition, enumerable smaller meetings have been taking place as needed by individuals working in common areas of analysis.

At present, several aspects of the data reduction process are complete but not yet published, these include the photomicrography, visible/UV spectroscopy and infrared spectroscopy and thermography. Because of the need for the utmost objectivity in our approach, logic and conclusions, we have decided to only release our information through professional refereed scientific journals. Since the correctness of our approach can only be properly judged by ultimate acceptance in secular scientific journals, we wait anxiously for their reply.

At present articles have been submitted to Science, Applied Optics, and X-Ray Spectrometry. Upon acceptance of these and other papers which we plan to submit in the near future, STURP plans to write a summary paper drawing together our concensus opinion of what our findings mean.

C-14 Dating

Before concluding this paper we think it important to mention here a few words on C-14. At the time of the October 1978 testing ordinary C-14 dating techniques required a significant portion of the Shroud to obtain even the crudest of dates. To destroy a significant part of the Shroud in order to "prove" its genuineness is the hight of folly!

Turin's reluctance to approve C-14 dating of the Shroud under these conditions has been prudent; however, in the past several years, new techniques have been developed that can provide a reliable date with standard deviation of 100 years from as little as a few milligrams of cloth mass. The application of C-14 dating to the Shroud is now reasonable, a thousand-fold less mass required than before! A proposal to date the Shroud by means of the accelerator/mass-spectrometer and newest C-14 proportional-counter procedure techniques has been submitted by the University of Rochester and the Brookhaven National Laboratory to the Archbishop. STURP, at the request of the Archbishop's scientific advisor, Dr. Luigi Gonella, has reviewed this proposal and concluded that such a test is vital to current scientific studies of the Shroud and that the new procedure is sufficiently reliable to warrant approval for dating. His Eminence--in conjunction with his designated scientific advisors as well as those of the Pontifical Academy of Sciences--is considering this proposal. We hope that a favorable decision will be forthcoming soon. Material sufficient for this test is available, having been removed in 1973 in the form of threads and two small swatches.[11]

Conclusion

At the start of this paper we mentioned that a team of scientists as capable as STURP would be a hard team to assemble given no restraints; however, interest in the scientific intrigue of the Shroud has accomplished what money and time could not. Table 1, reviews again the people, and

TABLE 1

MEMBERS OF STURP

NAME	AFFILIATION	SPECIALTY
Joe Accetta	Air Force Weapons Lab	Infrared
J. Sephen Baumgart	Air Force Weapons Lab	Infrared
David Bowman		Computers
Ernest H. Brooks II	Brooks Institute	Photography
Robert Bucklin	Houston Coroner's Office	Forensic Pathology
Don Devan	Oceanographics	Image Enhancement
Rudolph Dichtl	US Air Force	Electronic Physics
Joan Dichtl		Logistic Support
Robert Dinegar	Los Alamos Scientific Lab	Chemist
Thomas D'Muhala	NUTEK	Logistics
Mark Evans	Brooks Institute	Photography
Bob Ewing		Computers
Joseph Gambesia	St Agnes Medical Center Philadelphia, Pennsylvania	Medical Doctor
Dee German	Air Force Weapons Lab	Electronic Physics
Patsy German		Logistics Support
Roger Gilbert	Oriel Optical	Spectroscopy
Marian Gilbert	Oriel Optical	Spectroscopy
Thomas Haverty	Rocky Mountain Thermograph	Thermography
John Heller	New England Institute	Biological Chemistry
John Jackson	US Air Force Academy	Physicist
Kay Jackson		Logistics Support
Donald Janney	Los Alamos Lab	Image Enhancement
Joan Janney	Los Alamos Lab	Chemist
Eric Jumper	US Air Force Academy	Mechanical Engineer
Marjorie Jumper		Logistical Support
J. Ronald London	Los Alamos Lab	X-Rays
Jean Lorre	Jet Propulsion Lab	Image Enhancement
Don Lynn	Jet Propulsion Lab	Image Enhancement

The wives did not enter for the tests

NAME	AFFILIATION	SPECIALTY
George Markoski	NUTEK	Business Affairs
Walter McCrone	McCrone & Associates	Visible Microscopy
Vernon Miller	Brooks Institute	Scientific Photography
Roger Morris	Los Alamos Lab	X-Ray Fluorescence
Robert Mottern	Sandia Lab	X-Ray Radiography
Adam Otterbein	Holy Shroud Guild	Liaison
Samuel Pellicori	Santa Barbara Research Center	Optical Physics
Giovanni Riggi	Fiat	Microscopic Powders
Raymond Rogers	Los Alamos Lab	Physical & Organic Chemistry, Archiology
Larry Schwalbe	Los Alamos Lab	X-Ray Fluorescence
Barrie Schwortz	Barrie Schwortz Photography	Photography
Herb Sisson	Sandia Lab	X-Ray Radiography
Kenneth Stevenson	IBM	Public Affairs
Mary Stevenson		Logistics Support

affiliation of those people, who now comprise STURP. These are not people being payed to devote their time and effort to STURP but rather dedicated men and women who have nothing more at stake then to try and learn the truth about the Shroud. Their professional time has in no way been payed for by companies and institutions which employ them, nor has the normal time on their jobs been affected. The work represents the sole personal effort of the members involved and the money and equipment required to complete the tests came from the members involved and the contributions of foundations, companies and many interested individuals.

STURP is indebted to Cardinal Archbishop Ballestrero, and to all in the fine city of Turin who made this recent testing of the Shroud possible. For our part, we recognize the need to responsibly and professionally report our findings to the World community which we are now in the process of doing.

FOOTNOTES

1. The Shroud of Turin Research project did not become known as STURP until early 1979.

2. Rinaldi, Peter, "I Saw the Shroud," Sign Magazine, 1934.

3. Vignon, Paul, and Wuenschel, Edward A, "The Problem of the Holy Shroud," Scientific American, Vol 93, March 1937, pp. 162-164.

4. For Example: Sava, Anthony, "The Wound in the Side of Christ," Catholic Biblical Quarterly, Vol XIX, No. 3 (July 1957) pp. 343-346.

5. Stevenson, Kenneth E. (editor), Proceedings of the 1977 United States Conference of Research on the Shroud of Turin, Hold Shroud Guild, Bronx, NY 1977.

6. Jumper, E. J. and Jackson, J. P. (editors), Workshop Proceedings of the 1977 United States Conference of Research on the Shroud of Turin, Albuquerque, NM, March 24, 1977.

7. "A Proposal for Investigating the Shroud of Turin by Electromagnetic Radiation at Various Wavelengths," submitted to the International Center of Sindonology in Turin, Italy in September 1977 by the Holy Shroud Guild.

8. "Operations Test Plan for Investigating the Shroud of Turin by Electromagnetic Radiation at Various Wavelengths, submitted to Archbishop Ballestrero through Prof. Gonella in Turin, Italy, in October 1978 by the Shroud of Turin Research Project Inc.

9. Prepared in part by Katherine Jackson.

10. This paragraph prepared by Samuel F. Pellicori.

11. This section prepared in part by Robert Hudson Dinegar.