

CASE REPORT

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Diary of an Astronaut: Examination of the Remains of the Late Israeli Astronaut Colonel Ilan Ramon's Crew Notebook Recovered After the Loss of NASA's Space Shuttle *Columbia**

ABSTRACT: Two months after the fatal re-entering into the Earth's atmosphere of Columbia flight STS-107, the remains of Israeli astronaut Colonel Ilan Ramon's Crew Notebook were found strewn in a field in San Augustine County, TX. The random pile of papers was found to have survived the calamity of the Shuttle's disintegration remarkably well. Most of the papers recovered were torn and/or washed out to varying degrees but only mildly charred around the edges. The sheets of paper could be categorized into four groups: *Group I*: eight sides of paper written while in space in black ink and in pencil—Ramon's personal diary; the writing on these eight sides of paper survived well and is only missing where the pages were torn. Small fragments found in the field were physically matched to holes in the pages thus locating their original positions in the text. *Group II*: six sides of technical preparation notes written by Ramon before the mission. The writing on these pages was washed out entirely, but much of it was visualized using infrared luminescence. *Group III*: eight sides of personal notes prepared by Ramon before the mission written in blue ink. The writing on these pages was barely visible to the naked eye and not visualized by infrared luminescence, but was made largely legible by digital enhancement imaging. *Group IV*: a few sides of printed technical information. These pages were mostly intact and were not examined at length as they contained standard printed material. After completion of examinations at the Questioned Document Laboratory of the Israel Police, the diary was transferred to the Paper Conservation Department of the Israel Museum for preservation and strengthening treatments.

KEYWORDS: forensic science, questioned documents, fragments, infrared luminescence, digital enhancement photography, space shuttle Columbia

NASA's Space Shuttle Columbia, flight STS-107, took off from the Kennedy Space Center on January 16, 2003, on a 16-day mission. While orbiting the earth, the seven-man crew conducted a wide variety of experiments and intermittently stayed in contact with Earth through email and carefully timed public announcement broadcasts.

On re-entering the Earth's atmosphere on February 1, the Space Shuttle broke up, most likely as a result of damage inflicted to the spacecraft soon after takeoff, tragically killing all seven crewmembers.

Extensive searches were conducted in the crash area to recover any material that may have survived and 2 months later a pile of papers containing Hebrew writing was found in a field in San Augustine County, TX (Fig. 1).

Once it had been verified that the pages were indeed part of the Shuttle debris, the papers were collected and returned to Ramon's family.

Ramon's widow, Rona, decided to bring the papers to Israel for deciphering and ultimately, conservation.

When the pages were handed over for examination, it was stressed that the contents of Ramon's personal diary were to be kept well guarded and secret, being the treasured property of his family.

Consequently, the examiner had hoped to delve as little as possible into the content of the diary, but soon realized that in order to attain any measure of success, it was necessary to read its contents in detail and to closely study variations in Ramon's handwriting.

The papers showed a diversity of damage resulting from the highly elevated temperatures of the Shuttle's explosion, combined with damage sustained from exposure to the elements during the 2 months they were left lying in an open field.

The papers could be categorized into four groups.

Group I

Eight sides of paper (four written in black fluid ink and four in pencil) were torn to varying degrees but were barely charred. The black writing ink was readily legible and showed no signs of water damage, although the ruled lines on the first three sides were totally washed out. Apart from the pages, there were several unattached fragments that contained traces of black ink. These eight pages were readily legible where not torn.

Group II

Six pages of water-damaged paper—the ruled lines were very blurred and no writing remnants were visible to the naked eye; the paper was slightly charred along the edges.

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FIG. 1—Remnants of Ramon's Crew Notebook as found in a field in San Augustine County, TX.

Group III

Eight pages of water-damaged paper with very faintly visible remnants of writing in blue ink—enough to tease the eye in seeing that something had been written there, but nowhere near clear enough to decipher the content. These papers too were slightly charred along the edges.

Group IV

Several pages of printed technical information. No reconstruction work was required in order to read their content.

It should be noted that there is no information available as to where the Crew Notebook was stowed during re-entry. Several possibilities have been suggested—in a pocket of Ramon's space-suit, in a heat-resistant container, or simply under his leg (as suggested by one astronaut).

Methods

Before the pages were examined in the Questioned Document Laboratory, they were treated for 10 days in a thymol fume cupboard at the Israel Museum's Paper Conservation Laboratory. Some of the papers had yellow spherical spores attached to them, and this treatment was used to protect them from possible further damage by microorganisms that most probably contaminated the notebook while it was exposed to the elements.

All the handwritten pages received for examination had three punched holes along the margin and were of similar size. Several of the pages were still "bound" to each other by three partially melted plastic-coated rings. The pages received for examination were found to match a sample "Crew Notebook" received by the laboratory from NASA in both size and format. Some of the printed information found among the pile of papers was made up of larger sheets that had been folded.

The first page of Group I was in a relatively excellent condition, a remarkable fact considering the heat of the explosion, the altitude from which it had fallen, and the weather conditions to which it had been exposed. It was hardly discolored, but the bottom left-hand side of the paper had been burned away, leaving a gray-tinted charred edge.

Pages 2 and 3 of Group I were received completely stuck together, including several twisted and "traumatized" areas; they were pried apart with careful use of fine tweezers. These pages were very fragile and had the most internal tearing. Page 2 had

been most exposed to the elements and the face of the page was dotted all over with a yellow powder-like substance, identified as fungus spores, and likewise the reverse side of page 3. The face of page 3 was remarkably white, as it had been protected from external sources by being "stuck" to the reverse of page 2.

Page 4 was only partially intact and its outer edges had been torn away more than any of the others. The color of the paper seemed mostly unaffected.

Pages 5 and 6 had writing on both sides in pencil and suffered from the same random tears as the other pages written in black ink, but less fragmentation. Here too, the color of the paper was mostly unaffected.

The first page of Group I was headlined "... diary—Ilan Ramon astronaut"; this group contained Ramon's personal diary written while in space. The first four pages were written with black fluid ink that penetrated to the reverse side of the paper. A visiting NASA astronaut verified that the ink was most probably from a Sharpie® extra fine marker. The last two pages had writing in pencil on both sides of the paper.

The chronology of the diary's pages was determined by their content.

The paper of the diary's pages was quite badly torn in places; foreign objects had pierced some areas and the writing in those areas was missing.

The writing that remained was easily legible, although there were several segments across tears in the paper where the writing was more difficult to decipher. Several twisted or tightly curled fragments were received separately from the main pile of papers (Fig. 2a). It

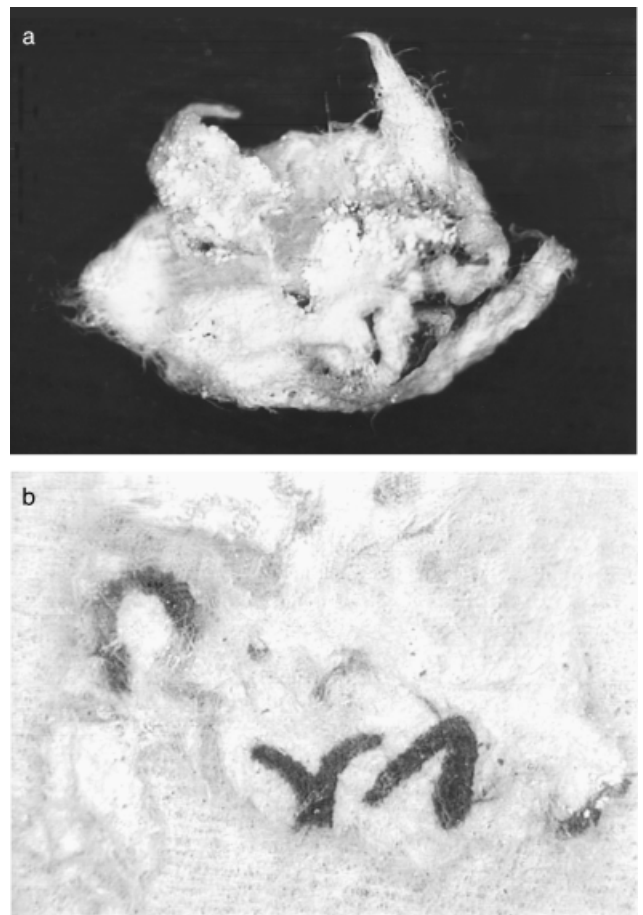


FIG. 2—(a) Curled fragment. (b) Same fragment uncurled and showing remnants of writing.

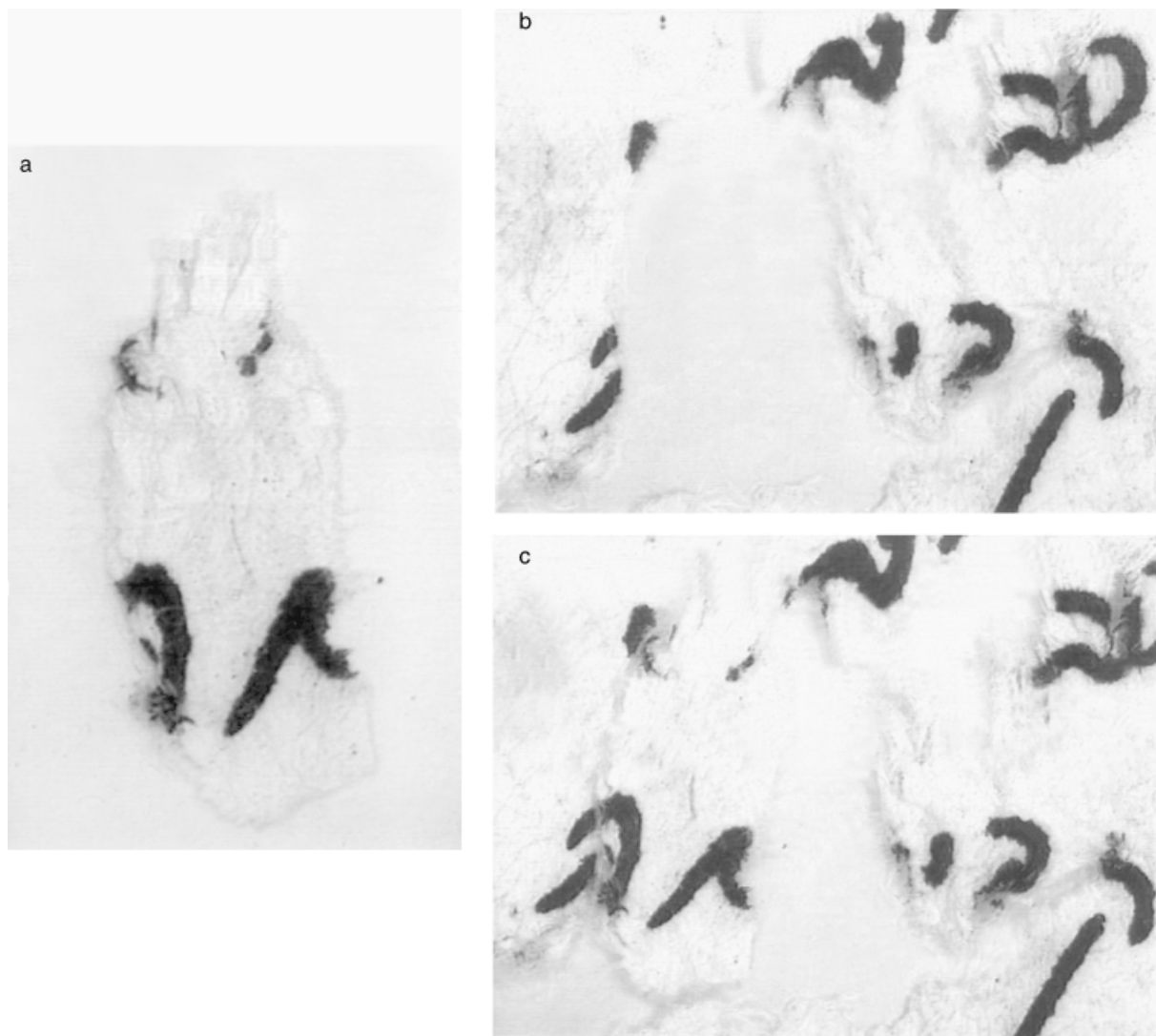


FIG. 3—(a) Fragment. (b) Part of page 2 of Group I. (c) Matching a fragment to its place of origin by its size, contours, and ink deposits.

was challenging to correctly place those fragments that contained remnants of writing (Fig. 2b) with their original locations.

The varying discolorations of the papers were helpful in matching the fragments to their original locations.

Further to discoloration of the paper, indications of where a fragment might fit were its size, shape, contours, and its remnants of ink deposits (Fig. 3a–c). It must be remembered that the papers had undergone traumatic conditions and tears in the paper could not be expected to show perfect physical matches as for paper torn under laboratory conditions.

Firstly, the content of the diary was read and hand-copied into the laboratory case file and where possible, missing letters or words that could be guessed were written with a dotted line. In this way, it was possible to search for parts of certain letters or words among the fragments.

After all the curled edges of the pages and their torn areas had been straightened out as much as possible, any new words or letters revealed were added to the laboratory file.

As mentioned, pages 2 and 3 were received stuck together. On the reverse of page 2 were images of the penetrated black ink from the face of page 2 and gray shadows originating from the face of page 3 (Fig. 4).

One of the fragments had several lines that could not be recognized as parts of any specific letters. The black ink of these lines had penetrated to the reverse side of the fragment, and in addition to them another letter was visible in its entirety in a shade of gray.

The fragment had originated from page 2 as the mirror image of the full letter on the reverse side of the fragment was matched to its source on the face of page 3 (Fig. 5).

One of the most interesting discoveries resulted from positioning a rather large fragment on the first page of the diary, Group I (Fig. 6a–c).

With placement of the fragment, the passage reads as follows:

The last traditional breakfast on Earth,
Get dressed in spacesuits, play the traditional card game
till
the last few seconds, go down in the elevator, out
to the astrovan with the last hand waves, the way to . . .

It seemed somewhat strange that the astronauts played cards after they had put on their bulky spacesuits and the authors wondered whether the fragment had been placed correctly, although its



FIG. 4—Reverse side of part of page 2, Group I. The darker lines are from the ink on the front of the page that penetrated through the paper; the gray lines are from the face of page 3 that transferred to the back of page 2.

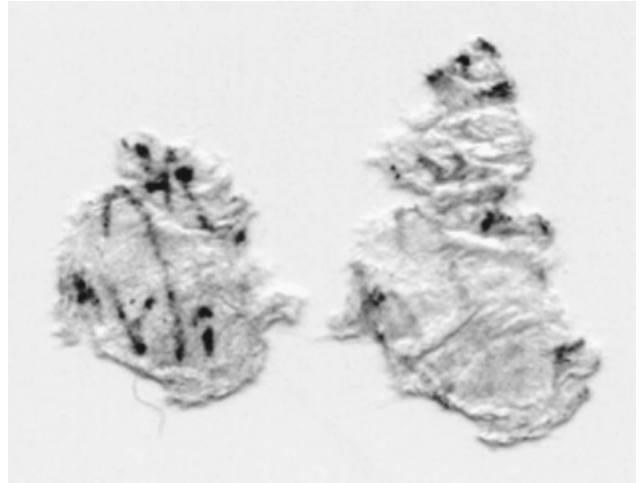


FIG. 5—On the left is the reverse side of a fragment from page 3, Group I, on the right, the reverse side of a fragment from page 2 where black and gray remnants are both visible. The source of the gray looped letter on the right fragment lies in the face of the fragment from page 3.

contours and ink deposits matched the gap in the page very well. Two NASA astronauts were asked whether they knew anything about the card game, but both replied that as they had yet to take part in an actual space flight, they did not know of any such tradition. Ramon's family and friends also had no light to shed on the question.

Three weeks later, one of the NASA astronauts replied that he had managed to verify that some crews did have a tradition of

playing a game of cards before the launch, believing it would bring them luck. Apparently, the crew continued to play until each astronaut had won at least once.

This information would have been lost without the correct placement of this particular fragment.

All in all, c. 10 fragments were matched to their original locations.

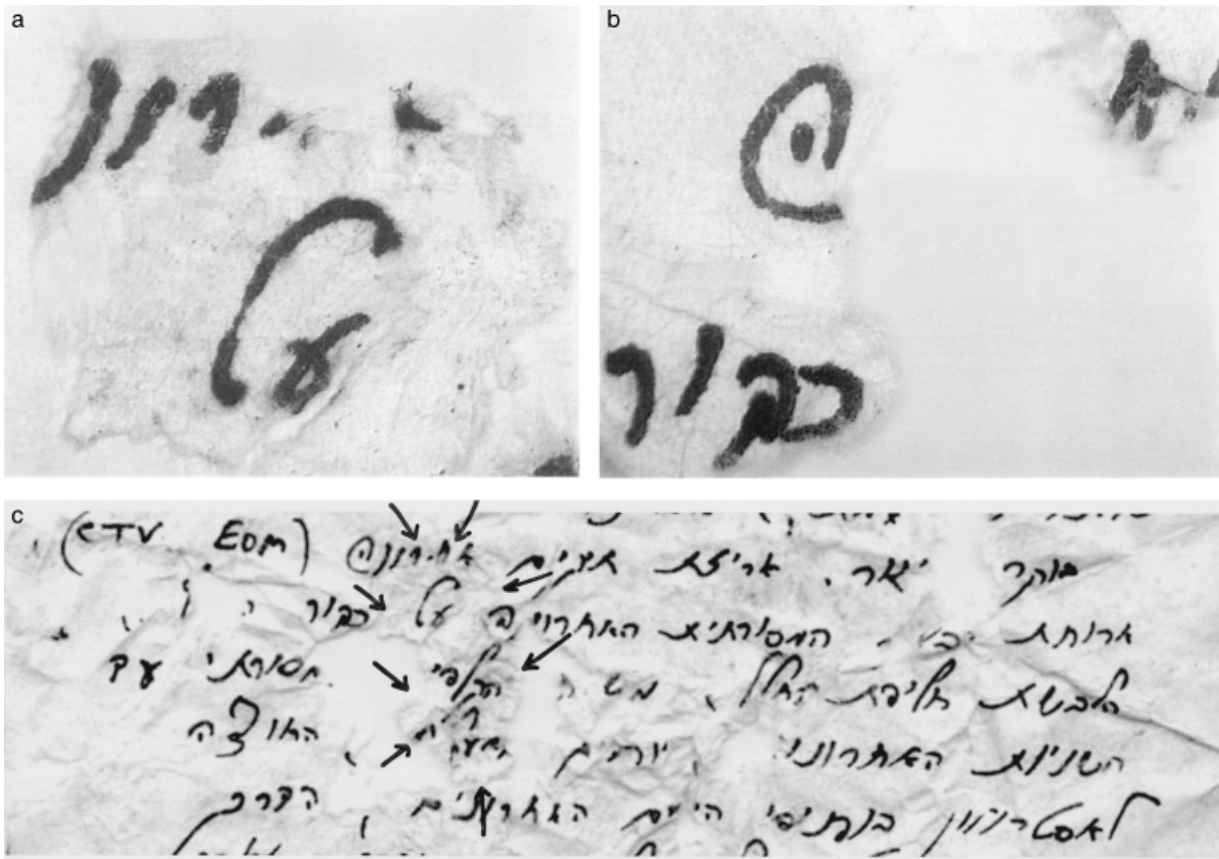


FIG. 6—(a) Fragment. (b) Gap in page I, Group I. (c) Placement of the fragment in the gap in the page—the arrows show the contours of the whole fragment.

It is important to point out that understanding the content was most valuable in deciphering the text of the diary. After the examiner's long and tedious deliberations over certain entries, a visiting member of the research team involved in the Israeli experiments on board the Shuttle read them quite effortlessly.

The entire diary covers the period from liftoff to flight day 6 (FD 6). It is not known whether there were more pages of the diary that were not found or whether Ramon stopped writing at this point. Several empty pages of the Notebook were found among the pile received for examination that revealed no traces of writing under any of the optical tests used. There is no way of knowing if these pages were earmarked for another purpose, or whether Ramon simply chose not to use them for continuing his diary.

All six pages of Group II appeared totally washed out with no plainly visible remnants of any form of writing.

The pages were viewed at various wavelengths, from the ultraviolet to the infrared (1) using the VSC-1, Foster+Freeman, England.

Infrared luminescence revealed that the pages contained technical lists made in preparation for the mission, including lists of medicines for different medical conditions relevant to space flight, and various safety and operating procedures.

Although the luminescence in the central areas of the pages was strong enough to "blind" the camera, a good part of the writing was deciphered (Fig. 7).

The eight pages of Group III proved to be the most challenging.

The first page had clear remnants of a washed-out blue ink, showing that the whole page had once been full of writing. Although several individual letters could be discerned, hardly one complete word was clearly legible. The other pages were more severely affected and hardly any letters could be discerned.

Using infrared, the pages were highly luminescent, completely blinding the camera. Ultraviolet light and reflectance in the infrared did not make the writing any clearer than viewing it in regular white light. Application of software tools to enhance the contrast between the traces of pale blue writing and the background was considered due to recent successes using digital enhancement photography (2,3).

As a first step, the pages were individually scanned using a flatbed professional scanner (Epson, Long Beach, CA) at 600 dpi and then processed using Adobe® Photoshop® (4) and Image-Pro Plus™ (5), increasing the saturation of the blue component. After trial and error, the best results were obtained by converting to the CIE $L^*a^*b^*$ color mode, choosing one channel, and using the "equalize" function with one of the software programs mentioned. Small areas of the resultant image were gradually "burned" and "dodged." This process increased the local contrast of the traces of writing against the background. At the same time as the contrast of the writing was increased, the "noise" from the background also increased and had to be subdued accordingly. This was done using a median filter or a "Dust & Scratches" filter. These filters also caused blurring of the writing and therefore the extent of their use had to be carefully controlled.

Some of the pages were processed with the "Channel Mixer" function in order to contrast the writing against the background.

Many hours of trial and error in working with the various applications achieved optimal results.

Amazingly, after processing the first almost blank page of Group III, a whole side of writing, a good percentage of it readily legible, was visualized on the computer screen and printed out on high-quality photographic paper.

The page contained a list of topics that Ramon had prepared before the mission and had intended to talk about during one of the public announcement broadcasts from space.

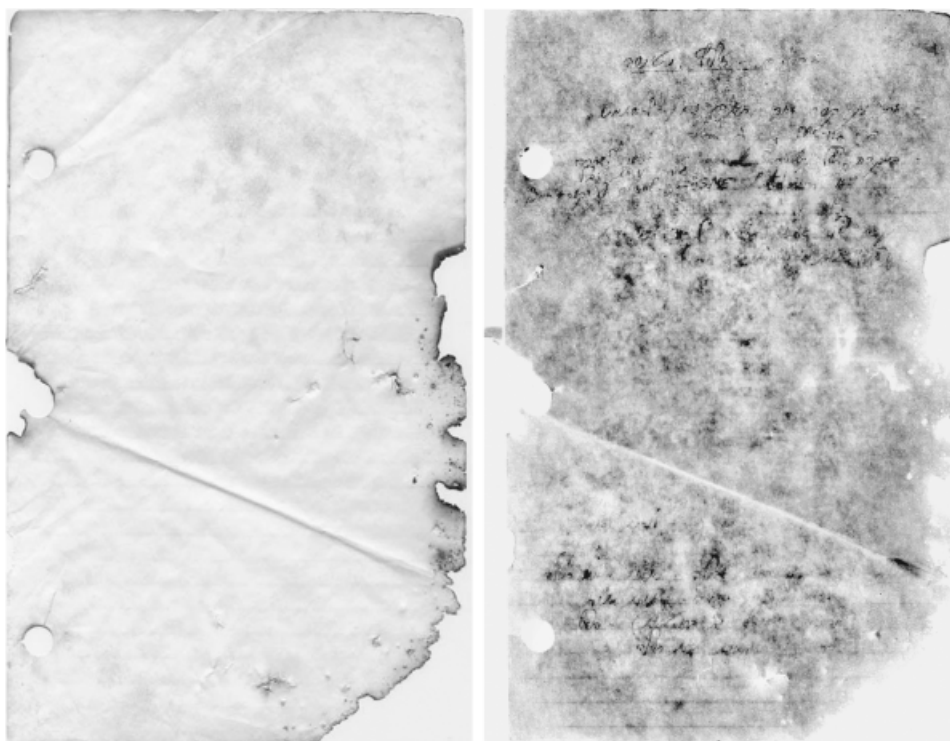


FIG. 7—The photo on the left shows a page of Group II with no visible remnants of writing. The photo on the right shows the same page as viewed with infrared luminescence.

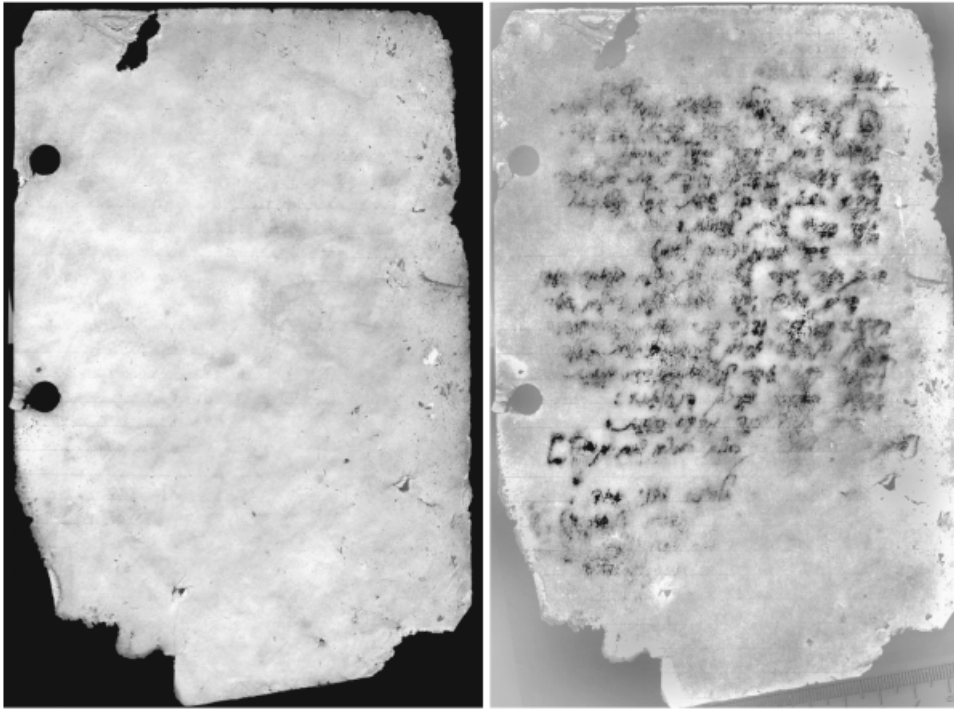


FIG. 8—The photo on the left shows page 2 of Group III with few very faint and blurred remnants of writing. The photo on the right shows the same page after processing with Adobe[®] Photoshop[®] and Image-Pro Plus[™]—“Kiddush.”

Page 2 of Group III showed slight traces of blue ink all over, but whereas on page 1 several letters were legible, here only one square bracket could be made out (Fig. 8).

Once again, after processing with digital enhancement software, a complete page of writing was visualized. The content was in Hebrew like all the other pages examined so far, but in contrast to them this writing was punctuated with vowels, unusual in everyday use of modern Hebrew. On close examination, several key words were recognized that led to deciphering the entire page—Ramon had copied out the special Sabbath blessing for wine, “Kiddush.” He had intended to say the “Kiddush” blessing on Friday night (sunset on Friday marks the beginning of the Jewish Sabbath), and had prepared the cup, grape juice, and blessing accordingly.

Two of the pages contain handwritten notes in Hebrew that have yet to be deciphered. It will probably be beneficial to give them to someone close to Ramon to try and read and give an educated guess to their content.

Conclusion

The examination of Colonel Ilan Ramon’s Crew Notebook proved to be a fascinating case and challenge.

The discovery of the Notebook 2 months after the loss of the *Columbia* provided the chance to learn more about the mission through the diary written by Ramon, Israel’s first astronaut.

The variety of techniques used to ultimately visualize the writing in the various pages of the Crew Notebook included those used in routine questioned document examination.

Remarkably, three different optical methods were needed to visualize the writing on the pages of each of the Groups I, II, and III. In other words, what worked well for one group was ineffective for another.

It is important to realize that despite the availability of digital enhancement technology, the forensic photographer spent many “human” hours in order to achieve the best results. This was by no means a case of scan, apply software, and see the results. Each area of the pages in question was treated individually, sharpening contrast in some places and reducing background glare in others.

The results obtained surpassed expectations by far and the contents that they revealed made all the effort worthwhile.

With the conclusion of the examination, the Crew Notebook was transferred to the Paper Conservation Laboratory of the Israel Museum. The diary fragments were fixed in place and a decision was made to protect the integrity of the pages as much as possible. Therefore, only a minimum amount of restoration was carried out, mainly to strengthen the pages, even though it was within their capability to restore the Notebook to “look like new.”

The pages of the diary and the Crew Notebook have a story to tell, through the writing contained within and no less by virtue of the fact that they survived the tragic loss of flight STS-107.

Acknowledgments

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We would also like to acknowledge the input of colleagues at the questioned documents laboratory in helping to match fragments to their correct locations in the text and in deciphering erased writings.

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