J13 Diary of an Astronaut: Examination of the Remains of the Late Israeli Astronaut Ilan Ramon's Crew Notebook Recovered After the Loss of NASA's Space Shuttle Columbia

Sharon Brown, MS, Questioned Documents Laboratory; and Laser Sin-David, PE, Photography Laboratory, Division of Identification and Forensic Science, Israel Police National Headquarters, Jerusalem, 91906, Israel*

The goal of this presentation is to reconstruct and visualize the handwriting, some completely erased and some visible but fragmented, on a series of highly traumatized documents, using classic and modern document examination methods.

Two months after the fatal re-entering into the Earth's atmosphere of Columbia flight STS-107, remains of Israeli astronaut Ilan Ramon's Crew Notebook were found strewn in a field in San Augustine County, Texas.

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 only mildly charred around the edges but were torn and/or washed out to varying degrees.

The sheets of paper could be categorized into four groups:

1. Ilan's personal diary, written while in space in black ink and in pencil; 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.
2. Six sheets of technical preparation notes written by Ilan prior to the mission; the writing on these pages was washed out entirely but much of it was visualized using infrared luminescence.
3. Eight pages of personal notes prepared by Ilan prior to 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 photography.
4. A few sides of printed technical information. The paper from these pages will be researched in order to learn how exactly the papers' fibres and makeup were affected by the explosion of the Shuttle.

With the conclusion of examination of the diary from the aspect of reconstruction and deciphering its contents at the Questioned Document Lab, it was transferred to the Paper Conservation Department of the Israel Museum for preservation and strengthening treatments.

Introduction: NASA's Space Shuttle Columbia, flight STS-107, took off from the Kennedy Space Center on January 16th 2003 for 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 1st, the Space Shuttle broke up, most likely as a result of damage inflicted to the spacecraft soon after takeoff; all seven crewmembers tragically perished. Two months after the disaster, during extensive searches to recover any material that may have survived the crash, a pile of papers containing Hebrew writing was found in a field in San Augustine County, Texas. Once it had been verified that the pages were relevant to the Shuttle debris, the papers were collected and transported to a storage hangar in Florida before being returned to Ilan Ramon's family. Ilan Ramon's wife decided to bring the papers to Israel for deciphering and ultimately, conservation.

Although the whole pile of paper had presumably suffered the same traumatic conditions of highly elevated temperatures when the Shuttle exploded, plus the approximately -60°C atmospheric temperature at the altitude where it broke up and then at least several days of wet weather during February and March, the papers showed a diversity of damage and could be split into four groups.

The first group comprising eight sides of paper (four pages written in black fluid ink and four sides of paper in pencil) were torn to varying degrees but were barely charred and did not show any signs of water damage to the writing although the ruled lines on the first three pages were totally washed out. These pages constituted Ilan's personal diary, written while in space and were readily legible where not torn.

The second group consisted of six pages of water-damaged paper – the blue ruled lines were very blurred and no writing remnants were visible to the naked eye; the paper was slightly charred along the edges, but not torn to the extent of the first group.

The third group had 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. The paper was slightly charred along the edges, slightly torn, and slightly water damaged.

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The fourth group of pages contained printed technical information. No reconstruction work was required here in order to read their content but these pages will be examined to learn more about the effects of the explosion of the Shuttle on the papers' makeup.

Remarkably, the writing on the first three groups of paper was ultimately visualized using three different methods commonly used for questioned document examination. In other words, what worked well for one group was ineffective for another.

It should be noted that there is no information available as to where the pages of the Crew Notebook were situated during reentry, for example if they were in a pocket of Ilan's spacesuit or in a padded, heat resistant container or simply held under his leg (as suggested by one astronaut).

Examination: When the diary was handed over for examination, it was stressed that its contents were to be kept well guarded and secret, as they were the personal property of Ilan's family. In order to conform to this wish, the author had hoped to delve as little as possible into the content of the diary and stick to piecing together the fragments like a puzzle. However, it was soon realized that in order to attain any measure of success, it would be necessary to become totally familiar with Ilan's handwriting style and become immersed in the content of the diary so as to be able to anticipate the words or letters that were missing in the hope of finding them amongst the ink deposits on the curled and twisted fragments.

All of 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" by three partially melted plastic-coated rings. A sample "Crew Notebook" received from NASA was found to match most of the pages received for examination both in size and format. Some larger folded pages were also found amongst the pile of papers containing Ilan's handwriting.

The first group of papers consisted of eight sides of clearly visible handwriting. The first four pages were written with black fluid ink that penetrated to the reverse side of the paper, most probably from a Sharpie® extra fine marker.[1] The last two pages were written on both sides of the paper, in pencil. These were the pages of Ilan's personal diary, written in space. 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; some areas had been pierced by foreign objects and the writing in those areas physically removed. The writing that had not been torn away was easily legible, although there were several segments across tears in the paper where the writing was more difficult to decipher. Furthermore, some of the pages were tightly stuck together and had to be pried apart carefully. At the same time, the pages were very fragile and along with the main body of paper there were several twisted or tightly curled fragments that had either broken off during the straightening process or were received separately from the rest of the pages. When straightened out, it was a challenge to correctly place those fragments that contained remnants of writing, in their original locations.

The entire diary covers the period from liftoff to flight day six (FD 6). It is not known if there were more pages of the diary that were not found or if Ilan stopped writing at this point. There were other pages of the notebook among the pile received for examination on which no writing was found, but there is no way of knowing if these belonged to a different section of the Notebook earmarked for another purpose, or if Ilan simply chose not to use them for continuing his diary.

It is important to point out that when deciphering the contents of the diary, an educated guess was most valuable. fter deliberating over certain entries for quite some time, a member of the Israel Air Force who had been involved in the Israeli experiments on board the Shuttle read those entries quite effortlessly.

The first page of the diary was received in relatively excellent condition, a remarkable fact in and of itself considering the heat of the explosion, the altitude from which it had fallen, and the weather conditions to which it had been exposed. The bottom left hand side of the paper had been burned away, leaving a gray-tinged charred edge. Pages two and three of the diary were received completely stuck together, including several twisted and 'traumatized' areas. Page two had been the most exposed to the elements and the face of the page was dotted all over with a yellow powderlike substance, actually fungus spores; likewise on the reverse side of the third page. The face of the third page was remarkably white, as it had been protected from external sources. These two pages had the most internal tearing and indeed most of the fragments were found to belong to them.

The fourth page was only partially intact and its outer edges had been torn away more than any of the others. The fifth and sixth pages were written on both sides in pencil and suffered from the same random tears as the other pages written in black ink.

After all the curled edges of the pages and their torn areas had been straightened out as much as possible, their contents were copied out in the lab file. Where possible letters or words that could be guessed, even though they had been torn away, were written with a dotted line. In this way, it was possible to search for parts of certain letters or words among the paper fragments.

The different papers also had varying colorations depending on exactly what they had been directly exposed to before they were found. Thus, as mentioned above, the face of page two had patches of a yellow powder like substance and page three being well protected was particularly white. The first page was hardly discolored but the left hand margin that had been burnt at the edge had a gray tone not seen on the other pages. The third indication of where a fragment might fit was its size, shape, contours and its remnants of ink deposits. It has to be remembered that the papers had undergone seriously traumatic conditions and tears in the paper could not be expected to show perfect physical matches as for paper torn under laboratory conditions.

On the face of one of the fragments were several lines that could not be recognized as belonging to 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 tone of gray on the reverse of the fragment. On closer examination it was found that the back of the second page showed signs of both the black ink that had penetrated from the face of the paper plus a gray 'shadow' resulting from transfer of a component of the black ink from the face of page three remembering that these two pages were received completely stuck together. The shape of the full letter on the reverse side of the fragment was matched to its source on the face of page three, and thus a site found for it on page two. The proper placement of the fragments made several words of the diary legible, whereas beforehand one could only guess what those words may have been. One of the most interesting discoveries resulted from positioning a rather large fragment on the first page of the diary.

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 it was wondered if the fragment had been placed correctly, although its contours and ink deposits matched the gap in the page very well. Two NASA astronauts were asked if 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. Ilan Ramon's family and friends also had no light to shed on the question.

Three weeks later a reply was received from one of the NASA astronauts who had asked around and learned that some crews did have a tradition to play a game of cards before the launch, believing it would bring them luck. This information would have been lost without the correct placement of this particular fragment. All in all, approximately ten fragments were returned to their original locations.

The second group of six pages appeared totally washed out with no plainly visible remnants of any form of writing. The pages were viewed with various light wavelengths, from the ultraviolet to the infrared using the VSC-1, Foster + Freeman, England.

With infrared luminescence, it was found that the pages contained technical lists made in preparation for the mission including lists of NASA personnel, 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.

The third group of eight pages 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 even more affected and hardly any letters could be read. In the infrared region, the pages were very highly luminescent, completely blinding the camera. Ultraviolet light and reflectance in the infrared did not help to view the writing any clearer than regular white light. It was decided to try digital enhancement photography in an attempt to enhance the contrast of the traces of pale blue writing.

As a first step the pages were individually scanned using a flatbed professional scanner at 600 dpi and then processed using Adobe® Photoshop® and Image-Pro Plus®, 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 "burned" and "dodged," bit by bit. This process increased the local contrast of the traces of writing against the background. At the same time as the contrast of the writing is increased, the "noise" from the background also rises and so has to be subdued accordingly. This was done using a median filter or a "Dust & Scratches" filter. These filters also cause blurring of the writing and therefore one must carefully control the extent of their use. Some of the pages were processed with the "Channel Mixer" function in order to differentiate between the writing and the background.

Although these applications are summarized here in a few lines, they took many hours of work to reach

optimal results. Amazingly, after processing the first almost blank page, 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 seemed to contain a list of topics that Ilan had prepared before the mission intending to talk about them during one of the public announcement broadcasts from space. The second page showed slight traces of blue ink all over, but where on the first page several letters were legible, here only one square bracket could be made out.

Once again, after processing with Photoshop®, a complete page of writing was visualized. The content was in Hebrew like in all the other pages examined so far, but in contrast to them, this writing was punctuated with vowels. On close examination several key words were recognized that led to deciphering the entire page – Ilan 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 and the blessing accordingly.

Two of the pages contain handwritten notes in Hebrew that have yet to be deciphered. As in examination of all the pages that were found, an educated guess is better than a random one, so that where there is no clue as to what the writing may contain it is very difficult to make head or tail of the content.

Conclusion: The examination of Ilan Ramon's Crew Notebook proved to be a fascinating case. Everyone had heavily felt the tragic loss of the Shuttle's seven astronauts. Over two months after the accident the discovery of the Notebook provided the chance to learn more about the mission through the diary written by Ilan Ramon, Israel's first astronaut.

From the first moment when researchers heard that the Notebook had survived the explosion of the Shuttle and that it had been found in the vast expanse of Texas, it was realized that this was no ordinary case. Indeed, the variety of techniques used to ultimately visualize the writing in the various pages of the Crew Notebook, covered a good range of techniques used in questioned document examination.

It is important to realize that despite the availability of wonderful digital enhancement technology, the forensic photographer spent many "human" hours in order to achieve the very 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 way surpassed expectations and the contents that they revealed made every bit of effort well worthwhile.

With the conclusion of examination of the Crew Notebook, it was transferred to the Paper Conservation Laboratory of the Israel Museum. Although work has just started on fixing the diary fragments in place, it has been decided to protect the integrity of the pages as much as possible. Therefore only a minimum amount of restoration will actually be done even though it is 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 the very fact that they survived the tragic loss of flight STS-107.

[1] As verified during a visit of a NASA astronaut to the QD Lab

Document Reconstruction, Infrared Luminescence, Digital Enhancement Photography

 ** Presenting Author*