A unique method of improving readability of old documents highlights examples of technology transfer in the fields of computer processing and communications systems

Making The Invisible Visible

Some 600 years ago, a Catalan physician named Arnald of Villanova wrote a treatise on surgical techniques of his day. Called *Speculum Medicine,* the work is invaluable to historians and medical researchers. Although much of the manuscript is well preserved, the toll of time has reduced parts of the text to faint, virtually invisible markings. But illegible portions, even sections that were once erased, have been made readable by a NASA image enhancement process originally developed to improve pictures sent to Earth from distant space. NASA's Jet Propulsion Laboratory (JPL), working with the California Institute of Technology, is now conducting demonstrations of the technology's utility for recovering such lost information.

JPL-Caltech researchers study an original medieval document preparatory to image enhancement. At right is the vidicon camera used to photograph pages for computer processing.

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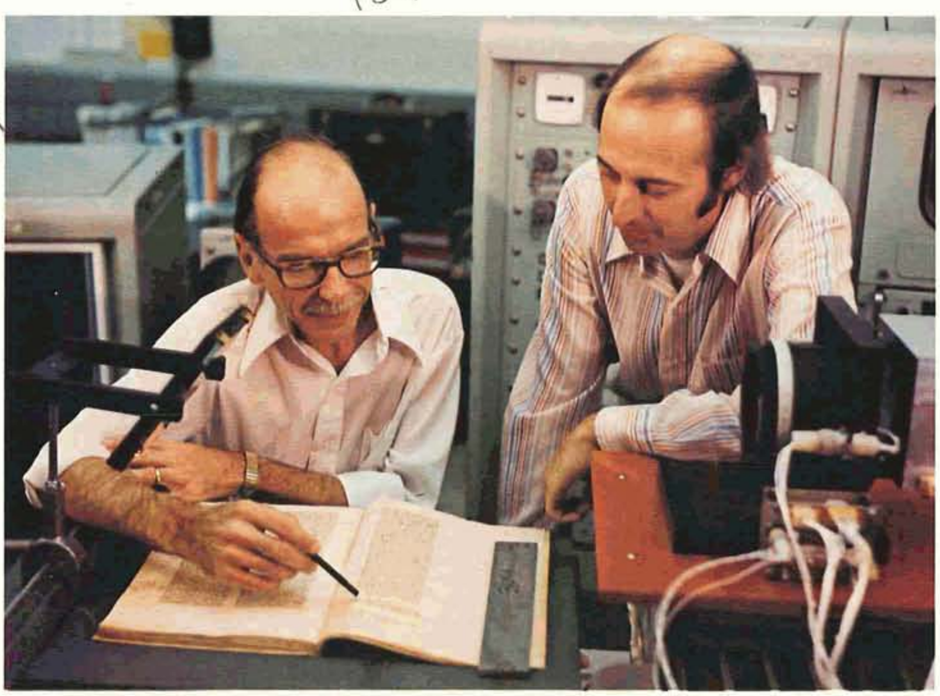

In public and private archives throughout the world there are many historically important documents that have become illegible with the passage of time. They have faded, been erased, acquired mold, water and dirt stain, suffered blotting or lost readability in other ways. While ultraviolet and infrared photography are widely used to enhance deteriorated legibility, these methods are more limited in their effectiveness than the space-derived image enhancement technique. The aim of the JPL effort with Caltech and others is to better define the requirements for a system to restore illegible information for study at a low page-cost with simple operating procedures.

The investigators' principal tools are a vidicon camera and an image processing computer program, the same equipment used to produce sharp space pictures. The camera is the same type as those on NASA's Mariner spacecraft which returned to Earth thousands of images of Mars, Venus and Mercury.

Space imagery works something like television. The vidicon camera does not take a photograph in the ordinary sense; rather it "scans" a scene, recording different light and shade values which are reproduced as a pattern of dots, hundreds of dots to a line, hundreds of lines in the total picture. The dots are transmitted to an Earth receiver, where they are assembled line by line to form a picture like that on the home TV screen.

But where television pictures are transmitted over relatively short distances, Mariner's images were relayed over tens of millions of miles, weakening in transit. That's where computer enhancement comes in; computer processing in effect amplifies the dots and lines, sharpening the image and revealing detail not originally visible.

In the document enhancing process, the vidicon camera scans a page and measures the brightness of hundreds of points along each line. The degree of brightness for each point is recorded on magnetic tape in digitized form, on a scale from zero for jet black to 255 for whitest white. The tape is then fed to the computer, which

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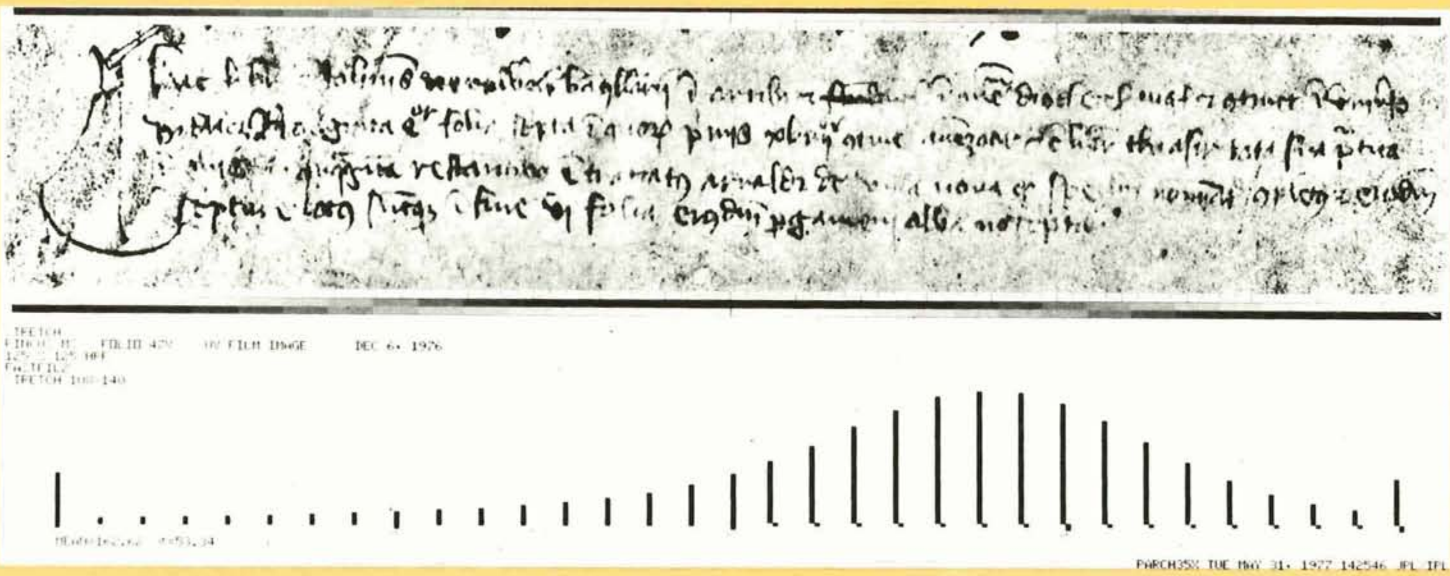
The photo at left shows a page of a 14th century medical treatise with once-erased, almost invisible marginal notes along the bottom. Below is an image-enhanced reproduction of the invisible lines. 136



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filters the data to remove background shading and sharpens the contrast to make otherwise invisible markings visible to the naked eye. The result is then played back and the reconstructed image is printed out.

This technique affords legibility superior to that attainable by other methods. Ultraviolet and infrared systems enhance writing or printed matter, but they simultaneously enhance the background, diminishing contrast. The space-developed combination of filtering and "contrast-stretching" produces the sharpest contrast possible with today's equipment. It can be coupled with ultraviolet and infrared images or used with direct visual lighting.

Much of the JPL work with Caltech has focused on *Speculum Medicine*, loaned to the investigators by its private owner, a California physician. Information illegible for centuries has been retrieved; for example, the process restored marginal notes that had been erased long ago and were almost invisible on the original parchment. The researchers have scored similar successes for other public organizations with old documents, such as a fragment of Cicero's *Republic*, the will of President Zachary Taylor, and legal papers from the 18th and 19th centuries.

JPL is continuing its document enhancing work, seeking to further advance the technique and to simplify computer programming. It has demonstrated the efficacy of the technology for transfer, but present operational procedures are too costly for wide application. The goal, considered feasible, is to design an affordable, readily operable image processing system that can be used by museums and libraries, either with their own equipment or through a commercial firm providing document improvement services.

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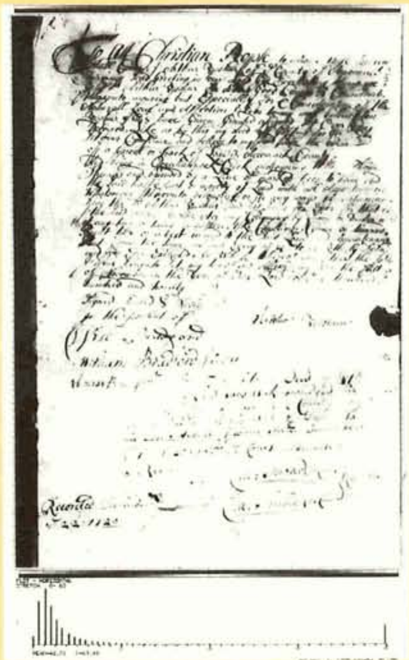
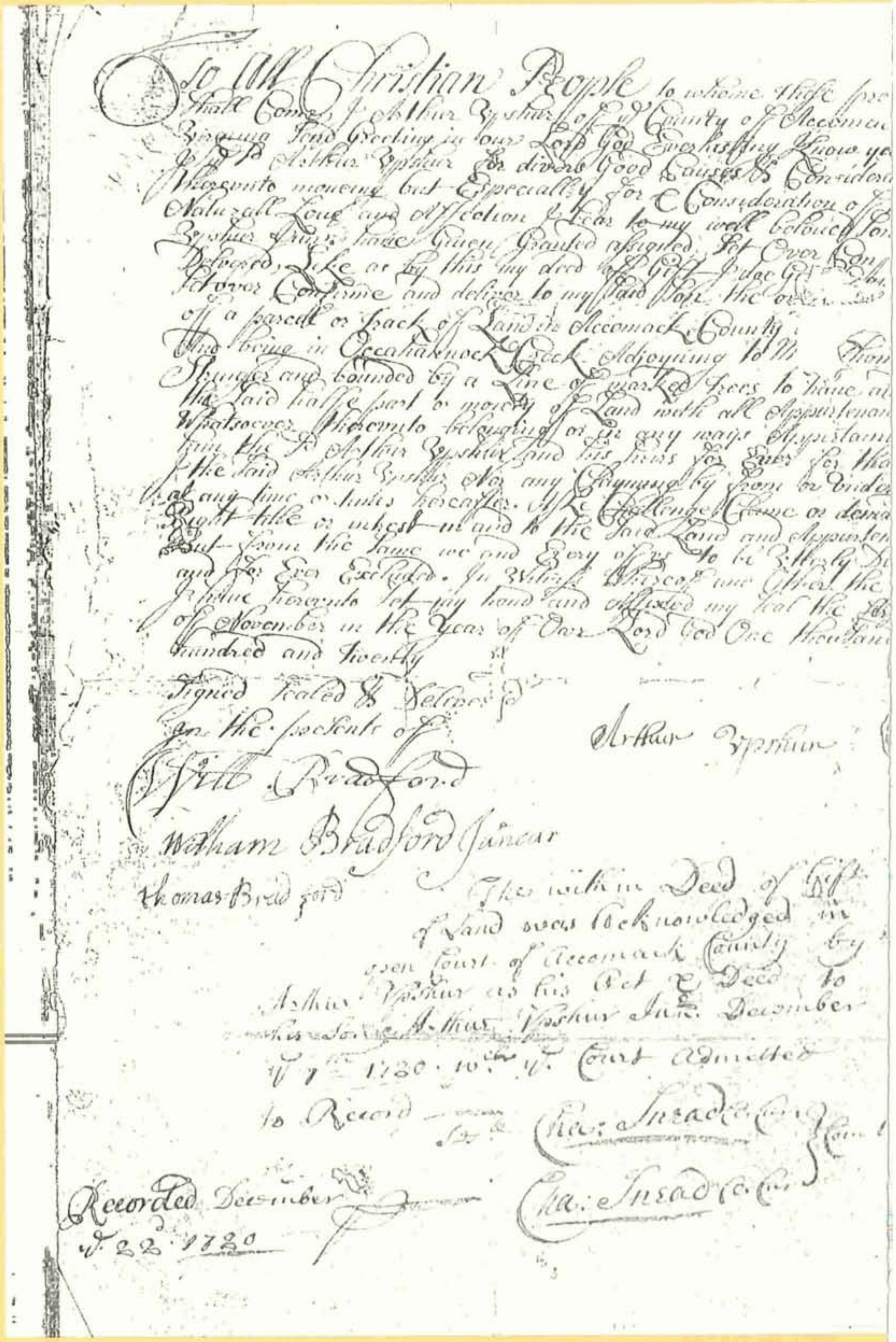


Known as "Mrs. Brally's document," this legal paper is more than 250 years old and the unenhanced original shows it; its smudges, blurs and varying contrast levels make it extremely difficult to read. The larger picture shows the same document, its legibility enormously improved after processing by Jet Propulsion Laboratory's computerized image enhancement technique.



To all Christian People to whome these pre[illegible]
Shall Come I Arthur Upshur of ye County of Accomac
Sending Fond Greeting in our Lord God Everlasting Know ye
that I ye Arthur Upshur for divers Good Causes & Consider[illegible]
thereunto moveing but Especially for ye Consideration of
Naturall Love and Affection I bear to my well beloved Son
Upshur Junr have Given Granted assigned Set Over Con[illegible]
Delivered Like as by this my deed of Gift I doe Give [illegible]
Set over Confirme and deliver to my said Son the [illegible]
of a parcell or tract of Land in Accomack County
And being in Occahannock Creek Adjoyning to Mr Thom[illegible]
Runnels and bounded by a Line of marked trees to have a[illegible]
the said halfe part or moiety of Land with all Appurtenan[illegible]
Whatsoever thereunto belonging or in any ways Appertain[illegible]
him the sd Arthur Upshur and his heirs for Ever for tha[illegible]
the said Arthur Upshur Nor any Claiming by from or under
at any time or times hereafter Any Challenge Claime or dema[illegible]
Right title or interest in and to the said Land and Appurten[illegible]
But from the same we and Every of us to be Wholy De[illegible]
and for Ever Excluded. In Witness Whereof we [illegible] the
[illegible] hereunto Set my hand and affixed my Seal the [illegible]
of November in the Year of Our Lord God One thousan[illegible]
hundred and twenty

Signed Sealed & Delivered
In the presents of

Arthur Upshur

Will Bradford
William Bradford Junear
Thomas Bradford

The within Deed of Gift
of Land was acknowledged in
open Court of Accomack County by
Arthur Upshur as his Act & Deed to
his Son Arthur Upshur Junr. December
ye 7th 1720. w^ch ye Court admitted
to Record Test Chas: Snead Cl Com

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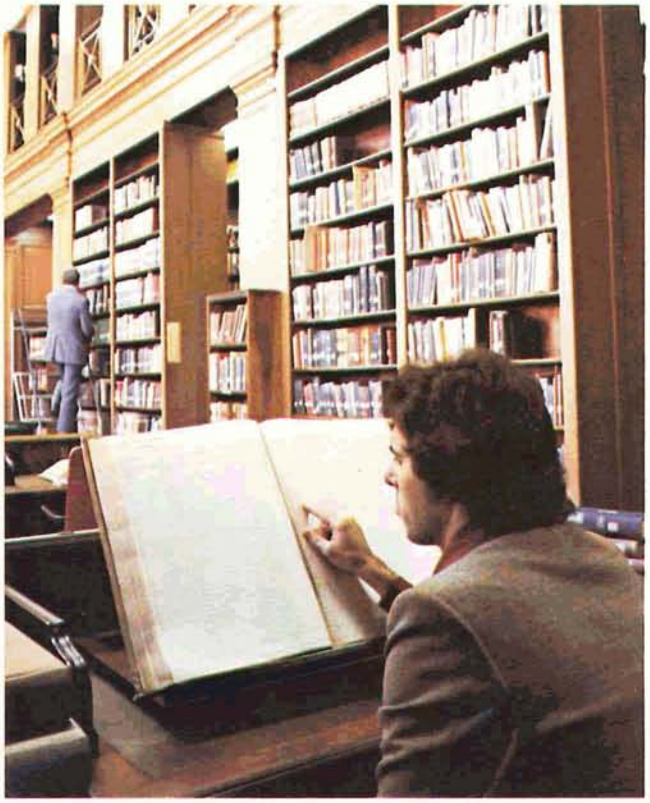

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Many museums and libraries have historically important documents whose contents have become illegible over a period of years. Skilled library technicians have methods and equipment for restoring lost information, but there is a need for a simple system that would enable scholars unskilled in document improvement to study illegible papers. Jet Propulsion Laboratory and Caltech are working toward design of such a system, an affordable, easy-to-operate image processor for general use.

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