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Final Endeavors of "Monument Man"

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Abstract

In 1973, as a Visiting Scholar at UCSD/IGPP (University of California, San Diego/ Institute for Geophysics and Planetary Physics, Scripps Institution of Oceanography), Mr. George L. Stout (1897–1978; co-author of the bible of art conservation: "Painting Materials, A Short Encyclopedia"; Director of the Isabella Stewart Gardner Museum; and co-founding Presidents of the International Institute of Conservation of Historic and Artistic Works as well as the later AIC) performed the first-ever experiments on laser divestment of embrittled varnishes from paintings. In that early year for laser technology, the only readily-available puled laser was an original Hughes ruby device (a copy Theodore Maiman's first laser) operating in the free-running mode. In spite of the very significant limitation imposed by the use of this primitive laser, he found that the varnish could be just crazed at the optical interaction threshold. Then, he found that the weakened varnish residue was easily removed with a moistened cotton swab. In the final years of his life (1975–1978), Mr. Stout participated in the founding of the UCSD-affiliated Balboa Art Conservation Center and the UCSD Center for Art/Science Studies (CASS). Through his affiliation with UNESCO, he initiated projects at CASS to employ laser divestment in saving the Egyptian temples at Philae. By 1978, his idea of utilizing digital computer image processing (borrowed from the SIO lunar space and moon-rock programs) had been pursued at CASS.

Keywords: Laser, Icon, Varnish, Gioconda, Leonardo, Philae

1. Background

The Science Advisor to President Richard M. Nixon (Dr. Edward E. David, Jr.) arranged for the leading USA laser scientists to assemble during the summer of 1971 to formulate a National Laser Research Plan. The most profound of the numerous recommendations that emerged from that policy study ("JASON 1971") led to a substantial expansion of the laser program at the Lawrence Livermore National Laboratory (LLNL) and the establishment of the National Ignition Facility (NIF) with what was then named the Nova Laser, as its centerpiece, for the attainment of thermonuclear Inertial Confinement Fusion (ICF). A footnote in the Final Report Executive Summary cites recent advances in pulsed ruby laser holography that enable in-situ creation of 3D diffraction-limited images of meter-scale subjects: far beyond the state-of the-art centimeter-scale objects of traditional laboratory holography. This technology had been employed to diagnose the performances of rocket-propulsion plasma jets and space-satellite microwave antennas. The JASON Committee noted that pulsed holography had the potential to record high-resolution 3D images of crumbling artistic treasures. Shortly thereafter, at the occasion of being inducted into the Club of Rome, JASON member Professor Walter Munk was able to negotiate an agreement with the Italian Petroleum Institute (ENI) to fund a holographic feasibility experiment to record for posterity archival 3D images, in-situ, of endangered Venetian sculptural treasures.

In the aftermath of the Venetian Holography project numerous museums (e.g. The Gardner Museum in Boston and the Smithsonian Institution in Washington) and universities (e.g. Harvard University and Massachusetts Institute of Technology in Cambridge) extended invitations for lectures on the holography project and subsequent discovery of laser divestment and cleaning in art conservation. Subsequently, it was learned that these invitations came in response to private disclosures by an interested prominent art conservator. The Venetian Laser Holographic and Divestment exploratory investigations were being promoted by George L. Stout, Director of the Isabella Stewart Gardner Museum, co-author of *Painting Materials, a short encyclopedia* (the bible of art conservation), co-founder and founding President of both the International Institute for conservation (IIC) and the American Institute for Conservation AIC), and recipient of both a Bronze Star (army) and the Congressional Gold Medal. Furthermore, he arranged (with Clements Robertson, Director, Nelson Art Gallery) for the laser work to be presented at the inaugural conference of the AIC in Kansas City (1973). The following three sections summarize the investigations that Stout insisted would transform art conservation practice.

2. Holographic replication and diagnostics

The ENI-sponsored (US $7,000) holographic conservation study took place in the winter of 1971 – 1972 and employed a 2J/pulse ruby laser oscillator and single-stage ruby amplifier yielding a coherence length of 10m. The holographic arrangement is shown in San Gregorio (Venice) together with its developer (Dr. Ralph Wuerker) in Fig. 1.

Fig. 1. Ralph Wuerker at S. Gregorio producing in-situ holograms of the Donatello *John the Baptist* carving.

During the three-month project, more than 50 transmission type archival holograms were produced of large (1 – 2m) stone statues, woodcarvings, and paintings by Donatello, Nino Pisano, Caravaggio, and other artists. The holograms were recorded on 12- and 25-cm glass plates and placed on display at the Academia Museum in Venice with HeNe laser illumination. A photograph of the reconstruction of one of the first in a series of Venetian holographic interferograms (the coherent interference pattern from superimposed holographic images) is reproduced in Fig. 2. In this example of holographic NDT (Non-Destructive Testing) the painted wooden leg of the Donatello work was subjected to a shift in humidity during the interval between a double-pulse exposure. The anomalous interference fringes reveal the locations of paint-layer detachments and subsurface cracks. Such interferograms may be employed to guide art conservators in repairing such defects [1].

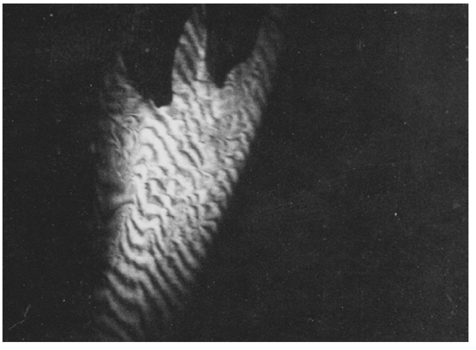

Fig. 2. Double-exposure hologram of the leg of the Donatello painted wood carving revealing hidden cracks.

3. Laser stone divestment in Venice

In the field of art conservation surface divestment frequently poses an array of vexing problems in the conservation, preservation, and presentation of artworks [2]. It is not uncommon to find that an encrustation, over paint, corrosion layer, soil, or biological growth to be removed is more durable (both chemically and physically) than its submerged artistic remnant. In traditional art-conservation practice the various mechanical and chemical surface treatments often attack the overburden and substrate with comparable vigor. Customarily, it is a matter of observation, skill, and timing that leads to maximum divestment with minimum damage or alteration to the fabric of the artifact itself. The problem of ancillary damage to artwork surfaces during cleaning is exacerbated by collateral health hazards to workers. Protective equipment to shield conservators from vapors, chemicals, and dust can impede the observation and control needed for precise and optimum treatment. Consequently, there has been a prolonged interest in discovering a new divestment technology that is free of the limitations of conventional chemical, mechanical, and abrasive methods. One such candidate is radiation-induced divestment employing non-toxic and environmentally friendly photons.

Toward the end of the Venetian holographic project in February 1972 G. Musumeci (conservator) was shown illustrations revealing impressive impulses delivered to surfaces through laser ablation (Figs. 3 and 4). She returned to San Gregorio from a meeting of the Soprintendenza alle Gallerie e alle Opere d'Arte del Veneto with the suggestion that stone cleaning be attempted by concentrating the ruby laser beam on a specimen of the black encrustation ("stone cancer") that was continuing to consume the city's marble monuments. She explained to the hologra-

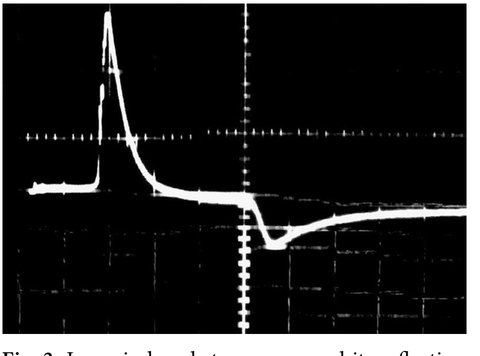

Fig. 3. Laser-induced stress wave and its reflection in a metal wafer.

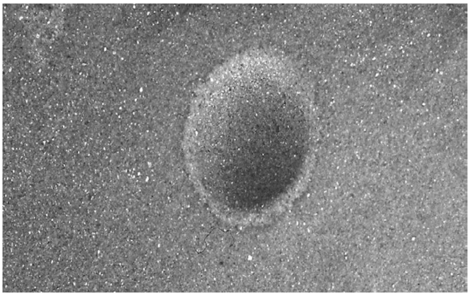

Fig. 4. Hypervelocity impact crater in a steel plate from a laser-propelled wafer.

phy team that outdoor sculptures in Venice were being "eaten" by the oxides of sulphur present in the local air pollution. In essence the air pollution destroys stone sculpture by converting solid marble (calcium carbonate) into granular gypsum (calcium sulphate). Conservation measures (cleaning, protection, and consolidation) were being impeded and avoided due to the propensity of the then current cleaning methods (abrasive, chemical, and mechanical) to damage friable stones. Proposed conservation projects failed to be granted official approval because available cleaning methods yielded an unacceptable patina with a "frosted" appearance. It was suggested that A. Schawlow's famous "laser eraser" technology [2] might be adapted to non-destructive and self-limiting stone conservation through the selective removal of black encrustations from crumbling marble sculpture without altering or damaging the weak surviving marble.

4. Initial laser projects

By March 1972, the holographic work had been completed. It was calculated that the 2J free-running pulses (non Q-switched with pulse length determined by pump duration) should be applied to 4 mm spots and that the 1J Q-switched pulses should be applied to 1 cm spots. During a two-day interval about fifteen Venetian monument stone specimens were test cleaned and parametric variations in laser flux and fluence were performed. The results were assessed by Superintendent F. Valcanover and Prof. L. Lazzarini for the Veneto and Mr. K. Hempel of the Victoria and Albert Museum for the Venice in Peril Fund. The three were in accord that every result was superior to conventional surface divestment in aesthetic patina and avoidance of surface damage [3]. Consequently, a series of laser-divestment major stone-conservation projects followed, beginning with the Cremona Cathedral (Fig. 5).

The 3D archival holographic recording proceeded with the assembly of images of Greek and Roman antiquities at the Getty/Malibu Museum (Fig. 6).

5. George Stout at UCSD (1974–1977)

In September 1973, two advisors to the World War II staff of General Eisenhower met for the first time in a hospital room in San Diego, California. George Stout, retired Director of the Gardner Museum of Boston, had led the *Monuments Men* (played by motion picture

Fig. 5. Cremona Cathedral laser restoration team at the project site (1990).

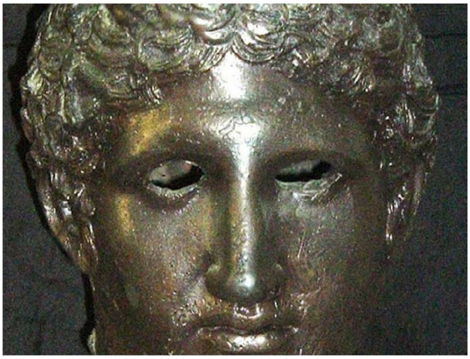

Fig. 6. Getty bronze of a young Greek that was holographically reproduced in 1974 for the opening of the Museum.

actor George Clooney) in recovering World War II looted artworks. Professor Walter Munk, (recovering from a skiing accident) was an Associate Director of the Scripps Institution of Oceanography/Institute for Geophysics and Planetary Physics (SIO/IGPP) and had led the team that forecast the sea conditions for the WWII Normandy invasion sites and selected an optimum date for the Allied landings. At their hospital meeting, the pair set in motion events that led to the establishment of the Balboa Art Conservation Center as well as the UCSD Center for Art/Science Studies (CASS).

Initially (1972–1974), laser cleaning tests and post-cleaning diagnostics at UCSD focused on a wide variety of antique stone specimens from monuments and buildings of Venice and London. This was a consequence of the major role in the laser evaluation program that was assumed by Sir Ashley Clark and Kenneth Hempel. However, George Stout's entire career had centered on paintings. His consulting tasks at The Timken concerned paintings, and he had just completed the second edition of his 1948 monograph: *The Care of Pictures*. Thus, it is understandable that he was eager to explore laser-ablation technology for improved conservation of paintings, rather than objects of stone, metal, ceramic, glass, or wood.

The CASS scientists and graduate students were uniformly skeptical as to the likelihood of Stout having any success in selectively removing a somewhat transparent varnish layer from the polychromatic paint layer of a painting with a single wavelength long-pulse ruby laser (Fig. 7). To the surprise of all, he discovered that by setting the laser flux at

Fig. 7. 1962 Hughes Company ruby laser copy of Theodore Maiman's original laser used by George Stout in the first radiation-divestment cleaning of a painting (Serbian Icon shown).

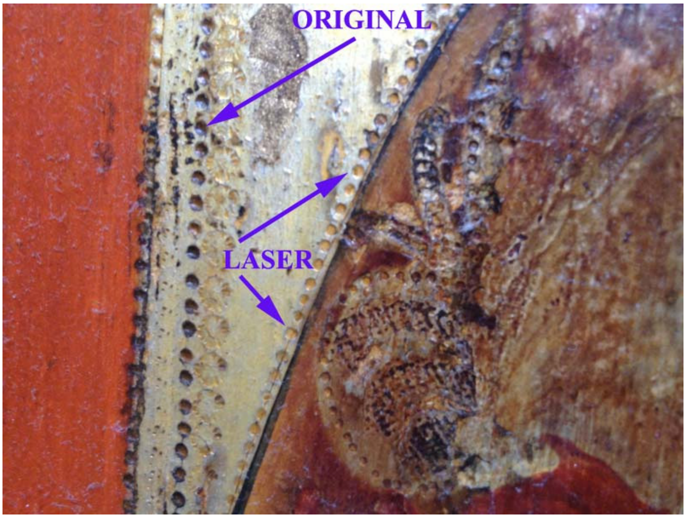

Fig. 8. Detail of a Timken Gallery Serbian icon revealing Stout's success in the laser-aided removal of darkened varnish residues from dimples in the gold gilding.

the interaction threshold, the varnish would be crazed just enough so that the degraded residue could be easily removed with a moistened cotton swab. However, patience was still required as several cycles of irradiation followed by swabbing was required to completely remove the varnish. Figure 8 shows what Stout had accomplished early in the process of cleaning one of the Serbian icons (*Lady of Tikhvin*) of the Timken Museum collection.

The introduction and commercial availability of newer high-performance systems such as excimer, erbium, picosecond, and femtosecond lasers has amplified the utility a much broader range of applications. Reliable and long-lived laser systems operating on the harmonics of the Nd:YAG wavelength have also opened new opportunities for the laser divestment of difficult materials such as papers and paints. The improved access to alternative wavelengths and shorter pulse lengths enhances the likelihood of avoiding thermal damage to fragile materials and the production of unwanted chemical ablation byproducts. Finally, it has become practical to employ multiple wavelengths, simultaneously, in order to lessen unfortunate outcomes such as the yellowing of certain marbles during laser divestment.

6. Laser removal of the Isis Temple of Philae painted stripes

Upon returning to UCSD from a UNESCO meeting on the fate of Isis Temple of Philae under the encroaching waters of Lake Nasser, Stout divulged that one of the problems facing the conservation teams in Egypt was the removal of painted white alignment stripes from some of the temple stones. He calculated that the laser radiation flux "window" for successful self-limiting divestment was 142–164 J/cm^2 at the 10.6 um wavelength of carbon dioxide lasers. It was proposed that a TEA laser divestment test would be performed on an Isis stone specimen supplied by UNESCO. First, the spot size for irradiation was adjusted for a flux of 50 J/cm^2. Only a single pulse was required to completely remove the white paint. A microscopic examination failed to reveal any sign of alteration (color or morphological) to the sandstone. A second portion of the paint stripe was irradiated at 100 J/cm^2. The results were indistinguishable from the earlier result. These observations deviate from the theoretical prediction. However, this is to be expected as the composition, consolidation, and homogeneity of both the paint and the stone are likely to be different from the handbook parameter values used in the calculations. The post-test condition of the Isis stone is displayed in Fig. 9.

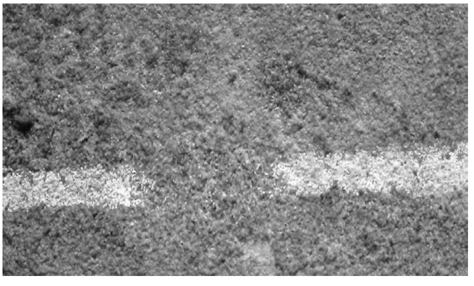

Fig. 9. A sandstone test block from the Isis Temple of Philae showing the region where the paintedwhite stripe was removed by CO_2 TEA laser self-limiting ablation (50–100 J/cm^2).

Plans were formulated, after the successful laboratory paint removal tests, for the laser treatment of the reassembled Isis Temple of Philae on the island of Agilkia. As schedules and costs were being determined, the onsite team made an unforeseen discovery. They found that environmental exposure (temperature excursions, sunshine, wind, and blowing sand) of the temple was leading to the gradual disappearance of the white stripes. Consequently, it was decided to let Nature take its course and just remain patient and await the eventual disappearance of the paint without resorting to laser ablation. The years following the Isis white stripe investigation have witnessed numerous examples of laser ablation of encrustations from dark substrates (e.g. [4] and [5]). Increased understanding, newer laser types, and improved models have all contributed to broader venues of success in such circumstances.

7. Digital enhancement of the "Mona Lisas"

When Stout first arrived at UCSD/SIO/IGPP in 1974 the major research activities there were concerned with the analysis of Moon Rocks and Lunar Imaging from lunar orbiting satellites. Upon touring the computer imaging laboratory at the Satellite Remote Sensing Facility (SRSF) he reflected immediately: "Couldn't we do computer image restoration of paintings?". During that era, the Voyager probes were intercepting Saturn, Jupiter, and the Jovian moons so that no time was available on the image-processing computers. Other visitors in those years, such as Prof. Carlo Pedretti, Prof. James Arnold, Mr. Walter Cronkite, Lord Kenneth Clark, and Mr. Thomas Hoving, offered similar suggestions, independently. However, it was not until 1985 that the IBM Corporation offered unlimited access to their Palo Alto Supercomputer before significant progress was possible in digital-computer image restoration to recover the original Mona Lisa from beneath the fog of the brown varnish layers, the web of cleavages, and the earlier restorations [6]. Figure 10 illustrates one of the results of that effort in removing the craquelure through FFT and Bi-scatter digital filtering.

Through the ages, prodigious energies have been absorbed into controversies about the execution date (or dates) of the portrait. The artistic, historical, and philosophical concerns that hinge on this are too numerous, convoluted, and erudite to be summarized adequately here. Suffice it to say that on

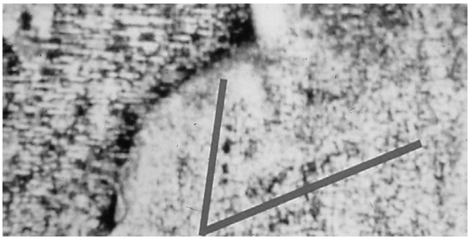

Fig. 10. *Mona Lisa* detail identifying varnish cleavages and craquelure (left side) by means of regional digital enhancement. The same numerical processing revealed vee-shaped pentimenti, indicating that Leonardo originally intended that the female figure wore a necklace (reproduced with permission from Mona Lisa Foundation).

largely stylistic grounds, Pedretti dates it to 1513–1516. The position taken by Lord Clark on historical evidence points to 1503 [7].

Also curious, is Leonardo's reason for producing duplicate versions of three of his other significant works. These are his *Virgin of the Rocks*, *the Virgin and Child*, and *the Virgin and Child with St. Anne*. Through the ages this recognition has triggered speculation that there may have been a second *Mona Lisa* by Leonardo, as well. A number of paintings have been advanced as the possible second *Mona Lisa*, only to be discarded after failing historical and/or scientific scrutiny.

The art connoisseur Hugh Blaker acquired a *Mona Lisa* painting in 1913 and placed it on display at his Isleworth studio near London. The apparent youth of the lady compared to the figure in the Louvre *Mona Lisa* as well as a completely different background clearly established that this painting was not simply a copy of the portrait in the Louvre. A number of art experts asserted that the painting, identified then as the *Isleworth Mona Lisa*, was of such a high quality that it had to be by the hand of Leonardo da Vinci. In a NY Times column, Paul G. Konody was unrestrained in his enthusiasm for the quality of the piece as well as its proportions and the arrangement of its elements [8].

By 1989, the *Isleworth Mona Lisa* had been in the hands of the Pulitzer Estate and an arrangement was made for a cursory scientific examination to determine whether the visual features of the painting were consistent with Leonardo's style and technique. This initial study was necessarily of limited scope as the artwork could not be touched or removed from its storage vault. Consequently, the analyses were performed on photographs taken at the storage facility in Lausanne. Upon digitizing these photographs and inspecting proportions and alignments it became evident immediately that the Isleworth painting was not a copy of the Louvre *Mona Lisa* that we had been studying and analyzing for the previous ten years [5, 6]. On the other hand, it was clearly demonstrated that the artist's strategy in aligning elements in the composition followed identical rules. In the subsequent 27 years, the Isleworth painting has passed virtually every comparative scientific test available in art conservation science with respect to the *Jaconde* portrait in the Louvre Museum. These tests include pigment analyses, multispectral and hyperspectral imaging, 3D imaging, isotopic measurements, geometrical analyses pertaining to the Vertruvian proportion and golden ratio, radiocarbon dating, infrared scanning, and digital-image age regression (employing FBI programs pertaining to facial recognition.) In addition, the *Isleworth Mona Lisa* has been visually inspected by a number of notable Leonardo experts [9].

8. Conclusion

When the first manuscript describing the laser project in Venice was submitted to a journal for publication (1972), it was rejected without the benefit of a peer review with the editor's dismissal: "Cleaning with lasers is too hypothetical to be taken seriously." In contrast, George Stout's entire career marked him as a true visionary and his very early advocacy of laser divestment, holographic and digital imaging, and radiation ablation of coatings on paintings and dark substrates revealed his creative personality. Stout's participation in the initial research projects at CASS dictated the vectors for their evolution and fruition. Subsequent to Stout's passing in 1978, all of these art conservation opportunities have matured and found widespread application.

During Stout's tenure at UCSD it seemed that his greatest passion was to see the *Mona Lisa* as the lady would have appeared to Leonardo at the time of the painting's creation before the unsightly restorations, the darkening of the varnish layers, and the development of the widespread craquelure. He (as well as Lord Kenneth Clark) voiced a similar sentiment that roughly stated was approximately "I would love to see the real *Mona Lisa* before I die" [10]. The Isleworth digital image restoration effort that emerged from Stout's suggestion progressed in that direction. Sadly, the image that Stout (and Clark) sought to see (Fig. 11) was produced about forty years too late for them.

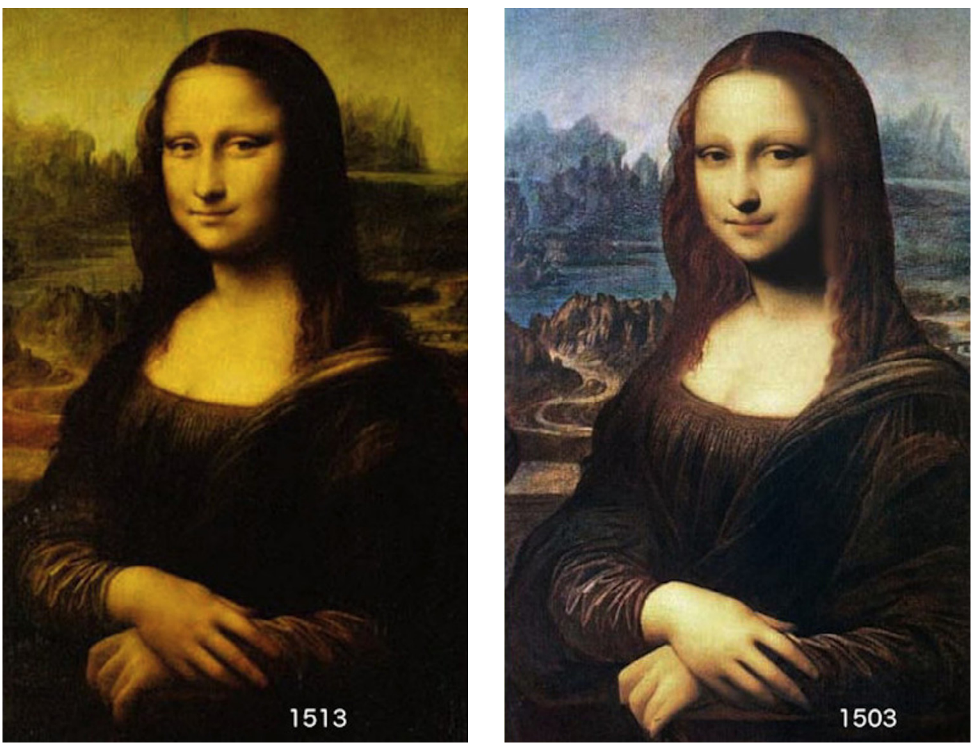

Fig. 11. The *Mona Lisa* in the Louvre Museum (L) and the Isleworth (Earlier) version (R) embedded in the digitally-corrected background of the Louvre painting (reproduced with permission from Mona Lisa Foundation).

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