From STEM to STEAM: Towards Aerospace Partnerships with Cultural Heritage Diagnostics

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***Abstract*— What would happen if archaeology and aerospace joined forces to test and develop new technology? Not only would it be the basis for an epic movie, there is considerable need in emerging fields of archaeology, like cultural heritage diagnostics, where a fruitful partnership could be forged. Both cultural heritage diagnostics and engineering groups share needs for multi-dimensional and multi-spectral surveying, immersive collaboration environments for visualizing results for analytics, and layered reality annotation systems to engage the scientific community and capture crowd-sourced feedback. The University of California, San Diego (UCSD) hosts the Center of Interdisciplinary Science for Art, Architecture, and Archaeology (CISA3), which is focused on engineering and adapting technology towards cultural heritage diagnostics for these purposes. CISA3 would like to build and consolidate new bridges between industry, academia, and government research to develop, test, and explain new tools to explore the cultural world around us with systems typically dreamt of in science fiction space exploration.**

Science, Technology, Engineering, and Mathematics (STEM) education and research is highly lauded as a means to maintain and improve society's problem-solving prowess. Recent years have seen a movement to put the Arts into the middle of STEM, thus transforming it into STEAM, to foster innovation and to deliver comprehensive, sustainable solutions to a wide range of problems and opportunities, especially those that are culturally sensitive. Utilizing this emphasis on an expanded definition of the 'arts' - specifically art, architecture, and archaeology a la CISA could help the aerospace industry and its many offshoots by both providing a culturally accessible entry point to engage the masses to recruit new generations of Indiana-Jones space exploration-engineers and act as a test bed for equipment and training. Deeper collaborations with aerospace offer cultural heritage diagnostics the chance to extend its ongoing dialogue between those who can identify practical field problems for which technology has not yet been invented, like archaeologists and art historians, and the computer scientists and engineers who are capable of constructing solutions.

This paper explores ways that cultural heritage diagnostics with CISA3 and similar organizations bridge the gap between pure and applied science in turn smudging the lines between the hard and soft sciences. It will explore the ways in which a STEAM movement focused not just on arts, but on art, architecture, and archaeology may be the path towards the productive and innovative collaborations between academia, industry, and government which have long been dreamed of, but not yet fully achieved. This paper will suggest ways in which cultural heritage diagnostics entities might partner with the aerospace industry to evolve well-rounded tools that reveal and preserve the treasure of our past to present audiences –to inspire and enable a future for humankind on and beyond planet Earth.

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1. INTRODUCTION

In contemporary society, science and the humanities have come to a veritable impasse in the United States of America. Both are under attack by budget-cutters and policy makers who wrongly deem humanities too soft and un-relatable towards technological and economically efficient progress [1][2] while simultaneously erroneously viewing science as too erudite and un-relatable to social concerns, and as a separate entity from any creative spheres. In a certain sense, each possesses what the other is judged as lacking. The humanities easily capture the public imagination and provide an in-road towards engaging and relatable communication for scientific endeavors and long-term support for science and technology. Science and technology,

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meanwhile, provide the humanities with opportunities to study itself quantitatively and in deeper detail than ever imagined previously while continuing their own course towards an innovative and streamlined future.

The two balance each other- as they have done for millennia- propelling themselves towards new heights of technological achievement. Indeed, for much of human history- the great scientists were the great artists and architects. It is only recent semantics and professionalization that have so separated the concepts of science and creativity in the public mind. In re-claiming the balance lost between the two over the past century, each will flourish[3].

The separation between science and the arts is epitomized in the distinction made between Science, Technology, Engineering, and Mathematics (STEM) education and its counter-movement Science, Technology, Engineering, Arts, and Mathematics (STEAM) education. However, in most applied uses, the 'Arts' category that has been added to seemingly create an efficient balance, is one that does not actually unite the STEM concepts with the humanities, but rather augments them through artistic endeavors. The 'Art' category deserves significant expansion from its typical definition, and when applied towards those aspects of study regarding art and human culture which are based on scientific endeavors, such as art history, architecture, and the archaeological past, it becomes a significantly powerful statement that could bridge the undeniable gap between the arts and sciences in both practical applications, education, and policy. In creating new technology geared towards studying the technologies of the past, so-called STEM fields quickly become STEAM and new opportunities for research which crosses the boundaries between academic and industry, and between pure and applied sciences, are thus born.

2. Bridging the STEM Gap with Cultural Heritage Diagnostics

The hard truth is that STEM fields like aerospace are in need of relevant humanities counterparts with significant scientific overlap but with approachable applications that are relatable outside the so-called 'hard sciences'[5]. Though the terms 'hard' and 'soft' sciences are debatable and philosophically the empiricism inherent within each negates the distinction, the looser connotations of the term to separate out the STEM related fields from social sciences and humanities will be used throughout the paper as the most appropriate divisor terms to label something which inherently, should never have been divided in the education systems [6].

Cultural heritage diagnostics provides considerable overlap which could be utilized to propel both fields farther – not just in terms of adjusting the general expectations and fractious categorizations that thus far define them, or in recruiting additional players into pursuing engineering fields- but towards establishing efficient means by which increasingly more useful, multi-purpose technology might be developed and tested. But before we delve deeper into the potentials of collaboration and the barriers such collaboration heralds, let us first introduce this likely collaborator. What is cultural heritage diagnostics?

Cultural Heritage Diagnostics: Introduction

Cultural heritage diagnostics is an emerging interdisciplinary field that utilizes science and technology typically applied in other, more industrial fields like aerospace and medicine towards surveying and analyzing monuments, archaeological sites and historical artifacts. In its widest definitions, it entails the application of data collection technology towards deeper and/or remote analytics of material culture and human ecological landscapes. For instance, the application of multispectral imaging on a painting to discern hidden features left by the artist or elemental analyses of the pigments in use to gauge the paintings veracity; the use of ground penetrating radar in ancient structures to identify secret rooms and the structural integrity of the building; the identification of archaeological sites via aerial or satellite imaging or their digitization via terrestrial laser scanning; photogrammetric techniques to visualize an underwater archaeological site for those on the surface – all of these activities fall under the purview of cultural heritage diagnostics. These are all data-

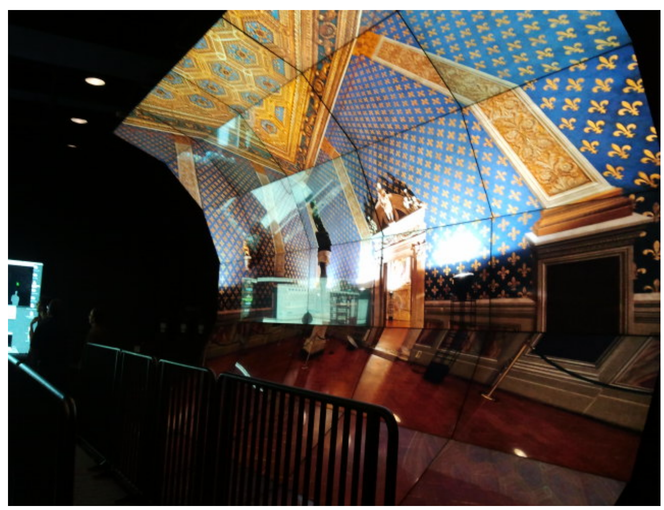

Figure 1 - An explorable stereoscopic image of the Room of the Lilies at Palazzo Vecchio in Florence, Italy displayed on the interactive Wide-Angle Virtual Environment (the WAVE) at the CISA3 Visualization lab in the UCSD Structural & Material Engineering Building.

gathering missions which utilize integrated technologies and methodologies to collect information, systems to process and visualize this wealth of information, and dynamic means by which it might be analyzed further from a distance by wider groups of experts and/or the public.

The data collection survey of a cultural heritage site or artifact is a severely time restricted and controlled activity which is dependent on a considerable amount of variables ranging from light and weather conditions to access. Cultural heritage sites are typically only available for a short amount of time, and are often inaccessible to the wider group of experts and potentially useful non-experts who might be needed to analyze them- either because of geographical remoteness, site safety issues, clean room conditions, or because of tourist traffic at high profile monuments (etc). This limits the amount of time and conditions under which a monument can be diagnostically surveyed for analysis and creates a need not just for new technologies which can perform a variety of diagnostics simultaneously and rapidly, but digital information systems in which all of this information can be organized for each isolated inspection, as well as in the form of a larger comparative 'big data' set of information relating to and preserving our knowledge about human history on Earth.

Cultural heritage diagnostics implicitly borrows and adapts existing technology already, and though it is beginning to develop new diagnostic imaging tools and systems for data visualization- this development would be streamlined if guided by the leading edge of similar development in long-established engineering fields like aerospace.

Cultural Heritage Diagnostics at the Center of Interdisciplinary Science for Art, Architecture, and Archaeology

The Center of Interdisciplinary Science for Art, Architecture, and Archaeology (CISA3) is located at the University of California, San Diego's Qualcomm Institute, a branch of the California Institute of Telecommunications and Information Technology (Qi/Calit2). CISA3's refined methodologies for conducting cultural heritage diagnostics projects focuses around a four pronged system emphasizing data acquisition at cultural heritage sites using integrated systems of technology for layered data capture, data curation of the multiple formats within the complex data sets, and the interplay of data analysis and data dissemination for both expert and non-expert review and active cognitive engagement. Throughout its workflows, it emphasizes the problem-identification and problem solving nature of the tasks. The emphasis at CISA3 is building a dialogue and encouraging interplay between the data collectors/consumers- the art historians, architects, and archaeologists- and the computer scientists and engineers who know what is possible with current technology and where the limits can be stretched to find new solutions. The field problem identification and lab problem solution feedback loop provides significant refinement in our equipment and systems deployment testing, which is further augmented by our efforts to have engineering components sent out on the field to phenomenologically encounter the challenges the data collectors face, and to have data collectors actively engaged in the development and processing phases of data collection, so that the challenges there are also realized and integrated back into field methodologies wherever possible and vice versa.

As a leading entity engaged in cultural heritage diagnostics and the engineering of technology specifically for cultural heritage, CISA3 frequently encounters some of the same field problems faced by their more easily recognized "hard science" counterparts in field exploration, in particular the aerospace industry. Like those in aerospace working on surveying other worlds, CISA3 is working on immersive and augmented reality visualization systems which will visually capture and correlate multi-dimensional and multi-spectral landscapes capable of displaying not just the physical information obtained through our remote sensing and other data collection campaigns but also possess annotation capabilities that allow both scholars and members of the public the ability to annotate the data and ethically cross-reference information about everything contained within.

Figure. 2 - CISA3 Terrestrial Laser Scanning and Thermal Imaging teams utilizing specially adapted automated turrets digitally documenting Castello Svevo di Rocca Imperiale in southern Italy.

This is currently centralized by an in-house software suite which efficiently handles large point cloud data sets [7] that can be overlaid with additional data and viewable in variety of systems, as well as the visualization systems themselves, including our large-scale multi-tile wall display systems, cave automated environments and augmented reality platforms.

Initially, CISA3's data capture emphases have been on the adaption and invention of diagnostic data collection technologies which are field-ready and capable of quickly collecting the desired data sets. This runs a widespread gamut of imaging devices, and associated platform, ranging from aerial drones for large scale overviews and photogrammetric reconstruction, to photography and thermal turrets for high resolution mosaic imaging, with an emphasis on adapted terrestrial laser scanning to create the point clouds which often act as the digital scaffold upon which all the other data sets are draped. New equipment is experimented with in our labs, tested locally, and then sent out to the field for further analysis of the system under the variety of environmental and man-made conditions we deploy them in- which ranges from arid desert, to urban museum, as well as underwater. Each test, including its use in the field, contributes greater refinements towards each project. The field-specialist, the engineers behind the systems, and teams of cognitive scientists work to build better, more useful and user friendly systems geared towards their exploratory purposes. Some, like our software systems and hardware for stabilization platforms have had great success, while others await the development of new, desperately needed technological development before success can be properly obtained.

CISA3 applies our analytical system at important cultural heritage sites all over the world- from the urban landscapes of historical sites in Florence, Italy like Palazzo Vecchio and Baptistery of San Giovanni in the complex of the Basilica di Santa Maria del Fiore, out to more remote archaeological sites in Mongolia and Jordan. At each site there are new data collection challenges, ranging from environmental to political, that have not yet been solved properly by the current suite of diagnostic imaging technologies [8].

Both the speed of data collection and the limitations of the equipment in terms of distance capture, resolution, and data integration hinder full analytical digital replication of any space or artifact. For instance, lower resolution digital landscapes of large sites and survey areas contextualize high resolution point clouds of specific sites (which are further embedded with increasing levels of detail) - but creating an automated system to place these multiple data sets into their layered realities is a daunting task. As is streamlining means by which this digital, augmented landscape can be navigated. How can we mitigate analytical gaps when looking back at the data in virtual space in different systems? How does one get past the distraction of the replicated space and allow for analysis as if it were the true space? Digital and 3D printed simulacra of sites and artifacts present an analytical challenge to our perception of phenomenological authenticity which must be mitigated both by increasingly higher resolutions of data generation and systems which overcome our analytical uncanny valley instincts in perceiving the replication as false.

Ideally, we are working towards creating a way in which space can be hyper-accurately reconstructed in a digital format for exploration and annotation. In pop culture terms , we are working towards building a workflow and visualization system like those hinted at in science fiction. An accessible and immersive Star Trek holodeck-like experience which could display real-time data built by diagnostic imaging devices akin to the LiDAR balls seen in the recent film Prometheus. The most recent CISA3 affiliated project, the Scalable Omnipresent Environment or SCOPE is geared specifically towards creating this kind of end visualization environment that would be needed for something akin to the holodeck. Phrased in such terms, it sounds rather fantastical, but we are always coming at this from a need based pragmatic approach- in order to display the wealth of shifting data that cultural heritage diagnostics collects, such visualization systems are necessary. Our STEAM feeds our STEM and our STEM our STEAM, each driving the other through loops of problem identification and problem solving. And what is most exciting- is that with each cycle of field seasons and technology development and deployment, we have made significant progress.

Figure 3 - An interactive mass point-cloud of the archaeological landscape of the Wadi Faynan of southern Jordan displayed on the multi-tile display wall of the Visualization Room at Qualcomm Institute at UCSD.

Figure 4 - Graphic conceptual visually depicting the layered data set and purpose of CISA3's work towards diagnostic data collection and public engagement in STEAM categories.

CISA3 began with a focus on layering multispectral imaging of famous paintings, and has expanded out from these singular artifacts to the analysis of full landscapes (the largest thus far, at 20 hectares) with a notion not just of multi-spectral imaging but of full layered realities of engaged multi-platform data sets draped over a 3D digital landscape and viewable in a variety of formats. In finding the ways to do what we have been doing, we have encountered a variety of intriguing data problems which we imagine are likewise plaguing the aerospace data infrastructures as well. How does one integrate and curate both the raw, processed, and media related content of the data set into a layered system [9]? How ought its associated metadata for each incarnation be tracked and accessed? It seems essential to maintain all the forms of data, metadata, and paradata- to distinguish between the raw formats of 'unbiased' data and the interpretative data. How can these complexities best be elucidated towards those attempting to analyze the results for their research without having to undergo significant training? In other words, how can one make a non-expert an informed explorer of the data [10]? As part of our larger goals, CISA3 is attempting to re-imagine how people interact with large, complex data sets through crowd-sourcing analytics [11], augmented reality engagement with direct scientific data, and applied cognitive science towards our user interfaces [12].

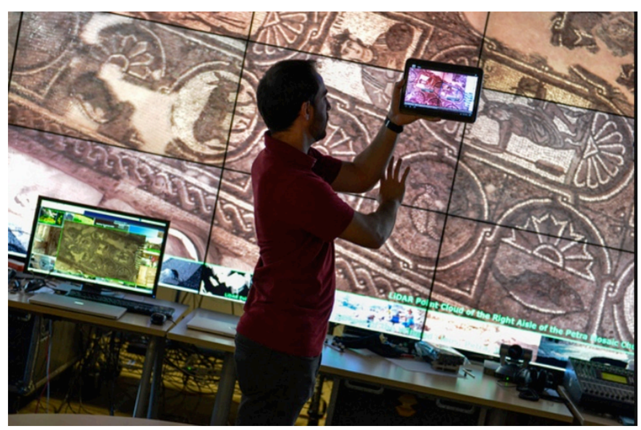

Figure 5 - CISA3's tablet based Augmented Reality viewer Artifact shown elucidating further information regarding the floor of the Petra mosaic floor displayed on the Optiportable movable wall display at Qualcomm Institute at UCSD.

Through these means we aim to connect an analytic and engaged public not just with their past, but with the means by which their past has been documented and displayed to them. Where the information came from and how it was transmitted is often just as crucial as the content itself. This means that alongside the cultural information- the rote dates of construction and snippets of historical lore- we are also attempting to build in levels of education regarding the scientific tools that gathered the data being looked at and the technology that makes such analysis possible. Often these are not considered or separate from the art, architecture, and archaeology dissemination and thus the engineering that went into them- the tools, the fieldwork, the processing stages, etc, are not considered as a part of the way the past is studied. CISA3 is attempting to rectify this misunderstanding between the study of history and culture and the usage of science to explore it that is interwoven not just into the storylines we are tracing, but into the way we are transmitting them to current and future audiences. Scientific education and policy runs complimentary to everything we are attempting to do in transitioning STEM to STEAM education and collaboration.

3. Collaboration Between Cultural Heritage Diagnostics & Aerospace

As an approachable concept which can advocate for the growing ubiquity of engineering, cultural heritage diagnostics could offer aerospace an approachable education outreach venue, as well as a potential test-bed for diagnostic tools. In return aerospace offers cultural heritage diagnostics an avenue towards scaling up the possibilities of technological development in terms of enhanced dialogue between the groups regarding the on-going construction of diagnostic imaging systems in the field and visualization correlation systems for analysis and dissemination in our respective labs and available to the public.

It seems promising that such collaboration take several formats, but imperatively that they take place at all. Though collaborations of this sort have been proposed previously, they do not often move forward or build from the ground up but are rather bureaucratic promises that fail to become deeply rooted in either community. For instance, consider the Chinese Academy of Sciences' International Centre on the Use of Space Technologies for Cultural and Natural Heritage (CEODE) established in 2011. The mission statement of the Centre bureaucratically proposes to apply existing space technologies towards cultural heritage preservation projects and yet has failed thus far in making contact with the wider global cultural heritage community, even failing to turn up to their proposed presentation at the inaugural United Nations Educational, Scientific, and Cultural Organization (UNESCO) International Council on Sites and Monument (ICOMOS) Digital Heritage International Congress in Marseilles, France in October 2013. Likewise, The UNESCO-European Space Agency (ESA) Space for Heritage Open Initiative established in 2003 encourages collaboration between space agencies and cultural heritage initiatives to share technology- but very little palpable movement has occurred, particularly in the development of any new technology with input from cultural heritage diagnostic entities. Though this has resulted in cultural heritage collaboration with aerospace towards data sharing for archaeological discovery, through satellite imaging, as well as movements towards a space archaeology dealing with conserving human material culture in space [13], particularly with the United State's own National Aeronautics and Space Administration (NASA)- it has not resulted in any significant pushes towards refining and developing new technology or educational outreach which would benefit both groups.

In order to effectively create collaborative solutions between aerospace groups and cultural heritage groups- it seems a more likely and practical solution that interdisciplinary networks of close-knit groups which revolve around projects should be created rather than waiting for larger bureaucratic entities to somehow enforce the collaborative philosophies they would like the world to espouse to coordinate something. In other words- better those of us actually in the field wanting these things to happen to do them, than that we wait around for someone to tell us what we ought to do.

Collaborative Design & Preliminary Field Testing

As indicated above, considerable problems arise in cultural heritage diagnostics both through the lack of the existing technology or through reaching the limits of the current technology. Often, despite lab testing, these issues are not reached until equipment and personnel are already out in the field and must make do with the limitations set upon them. Rather than deal with contrived field tests, why not streamline instrumentation and personnel training while simultaneously solving current problems in another discipline, in circumstances that easily translate back towards aerospace technologies initial exploratory goals.

We propose the formation of exchange groups where tiers of engineers from fields like aerospace accompany cultural heritage diagnostics projects performing earth-based forms of data collection comparable to equipment which is designed for extraterrestrial use. Establishing enterprise networks of communication between interdisciplinary researchers fosters development and perspective [14]. It also allows engineers to collaboratively experience a comparable high pressure, time-sensitive environment for collecting data that they would not be able to encounter through controlled testing. It has been an indelibly important aspect of CISA3 that our engineers go out in the field and are towards the problems they are meant to help solve. Likewise, it has been profoundly useful to have our cultural heritage practitioners engage in engineering and computer science research. This interdisciplinarity and shared perspectives on the lab and field work have been a shaping force in molding the interdisciplinary workflow and active communication between all aspects of our team.

We also, of course, further volunteer to test any equipment which could be useful to cultural heritage diagnostics in these settings to help determine limits and constraints which might not be noticeable under controlled testing conditions. As examples of the few remaining active field explorers, cultural heritage diagnostics and aerospace ought to utilize their shared emphases on fieldwork and make the most out of testing by evaluating off-world equipment terrestrially. Learning via textbook and observation are never as valuable towards acquiring the intangible trade-craft skills that build better systems. In this, it becomes not a matter of just merging the sciences and the humanities, but of unbuckling the distinction between scientific knowledge, technical knowledge, and field-know-how. There must be a balance between these which supports each other in feedback loops to optimize both the workflow training processes for field methodologies and the testing and quality control of equipment.

But more importantly than either the training or equipment sharing goals above, we would like to simply open direct channels of dialogue between cultural heritage groups and aerospace partners to actually get projects up and running. Theories and proposed centers are all well and good- but actual steps and results need to go forward to make good on the promise such a venture possesses. In an active, actor-oriented system of collaborative movements which specifically follow the technology- there is a higher likelihood for forward movement towards all of our goals [15]. Communication between the disciplines has been the crucible of our success at CISA3, it is time we likewise broke down the barriers between academia, industry, and government research and development and the barriers between science and the humanities.

4. From STEM to STEAM

To accomplish these goals, STEM education is simply not enough anymore to prepare the next generations of scientists for the kind of interdisciplinary and collaborative work that the future will require [16]. The United States of America is behind in adjusting towards the STEAM education which the rest of the developed world emphasizes as the best possible way to not only have science expand, but to have it do so with even more creative potential- a creative potential that is fostered in the 'A' within the acronym [4]. In order for the United States to catch up, its leading edges of cultural and engineering engagement need to be working together in order to push things efficiently forward.

Large scale community groups like the Humanities, Arts, Science, and Technology Alliance (HASTEC) and STEM to STEAM exist; and are making good progress towards STEAM- but, similar to the earlier discussed UNESCO groups, they are approaching from a bureaucratic philosophical perspective as opposed to an actionable pragmatic approach. And, crucially, they are approaching from an arts perspective as opposed to an engineering perspective. More worryingly for these groups, as we discussed at the start- the 'a' in STEAM is focused primarily on 'art' alone. STEAM needs to represent not just 'art' but other 'A's of cultural value as well, such as the 'architecture' and 'archaeology' also encompassed within cultural heritage diagnostics at CISA3. This enables greater levels of scientific dialogue to be mixed with wider anthropologically resonant examples. Just as STEM isn't enough, art alone is not enough within STEAM.

Joint Education Outreach Initiatives

In order for both aerospace and cultural heritage diagnostics to effectively proceed not just as their own disciplines, but to have an impact towards education and science policy in the future- considerable effort ought to also be applied towards education outreach initiatives- both separately, but especially jointly. It is a powerful statement for these disparate groups representative of hybrid potentialities between science and the humanities that while building systems that help study the past, they are also aiding in the construction of diagnostic survey systems that will aid mankind in the future.

It is essential that the public, and especially the age groups in K-12 education and college can actively engage with science and technology in innovative cross-disciplinary platforms [17]. CISA3 has been pushing forward on these notions of implicit education outreach in our work. A recent CISA3 project supported by the National Science Foundation (NSF) extolling 'hard science' topics through 'soft science' approaches here serves as powerful example. Onerously titled Sediment Intervals and Site Deformation Processes: Exploring Time Lapse Laser Scanning Capabilities and Methodologies for Archaeology, it was more widely known as Sandcastles for Science, the project looked at the possible resolutions laser and structure light scanning could acquire within landscape imaging. Sand, as a particularly flexible granular matter, was selected to stand in for the stratigraphic sediment layers at archaeological sites. Sandcastles were selected as landscape signifiers, both for their intrinsically architectural nature and that they are an engaging activity. By using the local Torrey Pines beach in southern California as our test bed for our diagnostic equipment, we were able not just to affirm the equipment's limitations towards our goals but high resolution imaging of granular matter in the field under time constraints, was not viable and that temporal point cloud software needed to be (and has since been) constructed in order visualize time-lapse sequences of erosion [18]), but to establish a rapport with the daily beachgoers- resulting in informal lesson plans for k-12 kids on everything from the ecology of the shoreline, Mayan step pyramid, Mesopotamian ziggurats, and Medieval Castles to laser scanning and the physics of granular matter, alongside the archaeological site deformation imaging methodologies we originally had set out to explain.

Figure 6 - Diagnostic Imaging Tests as part of the NSF CISA3 STEAM education outreach and equipment test project Sandcastles for Science.

The coating of the softer science and humanities of the archaeological goals and artistic sandcastle process made the harder sciences involved with lasers and geological morphologies easier to engage the public with as a starting point towards deeper levels of scientific dialogue. In other words, a spoonful of cultural heritage sugar, helped the science go down. This is, perhaps, a blueprint that could be followed to create and conduct wider scale education outreach that encompasses this kind of cultural heritage mantle draped over an engineering foundation.

5. Setting Precedents and Breaking Barriers

We exist in troubled times, where not only the truth of science is questioned by uninformed representatives of the nation [1][2][19], but where the group collective of collaborations and a belief in interdisciplinary research are falling out of favor as a means towards solving larger issues. Indeed, beyond that- we exist in a fractured time where research institutions are distinctly separated from industry and government development, despite the considerable overlaps in the concepts and the process of research and development for all three [19]. Though all three groups are conducting similar research, there is a distinct lack of networks established to encourage actual, constructive dialogue between them. Recent encounters in Washington DC with members of both the National Science Foundation and the National Academy of Sciences indicate that this split is considered the status quo. And more terrifyingly, that interdisciplinary and collaborative research itself – though desired – is considered impractical [21][22]. This seems to stem both from concerns over interdisciplinary collaboration acting as a distraction for those pursuing singular topics in academia and stable careers [23] and that the degree of success is variable and often has more to do with the social connectivity of the collaborative groups that are working together. Which, from a common sense perspective is practical- those who play well together can work well together much easier than those who do not [14][24][25].

Academia in particular should not be as disengaged with industry and government research and development. The ivory towers of the university systems need to be more intimately connected to the national and economic infrastructures which fund them. Scalability of projects is severely hampered by the tri-part split and, in particular, the competition that is implicitly encouraged between industry and academia for the best minds and for preliminary rights to inventions [26]. In academia this is consistently leading towards a plethora of published concepts that are never taken to fruition unless they are picked up by industry or government. And yet no system to ensure that this occurs, that projects concluded by academic criteria of 'publication-worthy' are followed up on in venues where further work to actually build the envisioned concept can be taken to fruition. The academic university system, though proposed as a locus between the three groups- needs to more thoroughly engaged in this in practice [27][28][29]. Cultural heritage diagnostics at the university level as something so perfectly poised between pure research science and the applied science of industry, and as something in need of further guidance from non-academic spheres, presents a perfect drive and conversation topic to unite these various influences and find the middle ground that the future of education policy and technological innovation so desperately needs.

Though it is rife with problems, it is also an exciting time- invention is occurring on a more rapid scale than ever before; and new technologies are not only appearing rapidly- their ubiquitous usage is reflected in rampant social change [30][31]. It should be one of the greatest moments in the development of technology for all purposes- but especially for technology related to diagnostic visualization. Not only is this an absolutely crucial system for capturing and conveying data related to mankind's exploration of our own atmosphere and the wider realms of space beyond, visualization diagnostics are critical in encapsulating our past as we know it- not just as a record, but as an analytical tool so that we can discover more about our past and determine the best structural and societal ways to have it be a continual part of our culture for as long as possible [32].

Fields that are working towards these common lofty goals should be talking- they should be collaborating- they should be building bigger systems which are formed through a wide range of perspectives. Given the profound overlap between the emerging field of cultural heritage diagnostics and the established aerospace community- there is extreme potential, not just for the establishment of a useful dialogue to refine and design new technology- but also to contribute towards a much needed movement in integrating the humanities back into the arts in terms of both practice and education.

6. Summary

This paper outlined the overlap between work conducted in the emerging field of cultural heritage diagnostics with respect to remote sensing, diagnostic visualization, and dissemination systems and their overlap with aerospace. It argued for collaborations to be set up between these two fields starting with exchanges of ideas into the development of new diagnostic technologies and opportunities for aerospace equipment and personnel to participate on cultural heritage diagnostic projects. It further made a case for collaborative education outreach ventures that emphasize the value of applied science in engineering in hard sciences like aerospace with the softer science of cultural heritage diagnostics providing an engagement mechanism, moving from STEM education towards STEAM education by deploying the art, architecture, and archaeology studied under cultural heritage diagnostics into the melee.

It is important that STEAM-influenced policy for scientific development be established between the so-called "hard" and "soft" sciences. The interplay of aerospace involvement with the development of technology for cultural heritage diagnostics would be a remarkable precedent towards the creation of well-rounded analytical exploration tools and visualization systems both for the current known expectations of data-gathering, as well as laying the path towards unknown but anticipated levels of data accumulation. It also sets a strong precedent for inter-field and interdisciplinary collaboration that contradicts recent concerns regarding both these ventures and pushes towards healing the separation of academic, industrial, and government research and development of technology.

As aerospace and other engineering groups build a future for humankind on this planet and beyond, it is a profound philosophical statement for them to have actively contributed towards the deliberate development of the tools and systems for cultural heritage diagnostics that are exploring and preserving our past.

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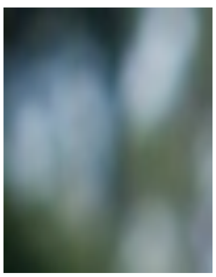
BIOGRAPHIES

Ashley M. Richter *received a BA Joint Honours in Archaeology and Ancient History from Durham University in the United Kingdom in 2007. She received an MA in Archaeology and Heritage from the University of Leicester in the United Kingdom in 2011. She is currently working towards her PhD in Anthropological Archaeology at the University of California, San Diego, working with CISA3 to evaluate interfaces between the development of technology and cultural heritage and the use of visualization systems for archaeological analysis and dissemination. She has worked on archaeological projects all around the world, including in the USA, the United Kingdom, Jordan, Cyprus, Greece, and Italy. She previously worked with the laser scanning for cultural heritage non-profit CyArk.*



Radley Angelo *is an undergraduate researcher with the Center of Interdisciplinary Science for Art, Architecture, and Archaeology (CISA3). In addition to long-term work as one of the CISA3 National Geographic Engineers for Exploration projects, he has lead remote sensing field work on the CISA3 project in Mongolia in the hunt for Ghengis Khan's tomb, and is one of the lead developers and field technicians of the CISA3 drone fleet for aerial imaging. He is currently transitioning into industry with his own aerial imaging venture Spark Aerial.*

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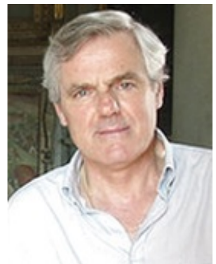

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