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# Futureproofing Visual Effects: Challenges and Strategies for Preserving Digital Assets and Records

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**Abstract**

Digital visual effects (VFX), including computer animation, have become a commonplace feature of contemporary episodic and film production projects. Using various commercial applications and bespoke tools, VFX artists craft digital objects (known as "assets") to create visual elements such as characters and environments, which are composited together and output as shots.

While the shots that make up the finished film or television (TV) episode are maintained and preserved within purpose-built digital asset management systems and repositories by the studios commissioning the projects; the wider VFX network currently has no consistent guidelines nor requirements around the digital curation of VFX digital assets and records. This includes a lack of guidance about how to effectively futureproof digital VFX and preserve it for the long-term.

In this paper I provide a case study – a single shot from a 3D animation short film – to illustrate the complexities of digital VFX assets and records and the pipeline environments whence they are generated. I also draw from data collected from interviews with over 20 professional VFX practitioners from award-winning VFX companies, and I undertake socio-technical analysis of VFX using actor-network theory. I explain how high data volumes of digital information, rapid technology progression and dependencies on software pose significant preservation challenges.

In addition, I outline that by conducting holistic appraisal, selection and disposal activities across their entire digital collections, and by continuing to develop and adopt open formats; the VFX industry has improved capability to preserve first-hand evidence of their work in years to come.

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# Introduction

Digital VFX is a specialist creative and technical field of media production that uses digital filming technologies, digital animations and other forms of computer-generated imagery (CGI) in situations where visual elements such as a scene, character or effect is required for a project, yet cannot be achieved during live-action shooting. VFX work generally involves combing CGI together with live-action shots, although VFX companies also work on completely CGI projects, such as 3D animation films.

Following a string of commercially successful, VFX film projects during the 1970s, including *Star Wars* (Lucas, 1977), *Alien* (Scott, 1979) and *Star Trek: The Motion Picture* (Wise, 1979), digital VFX has evolved into a key component of film and television (TV) (Venkatasawmy, 2013), now accounting for up to 40 per cent of spending on productions (Rüling and Duymedjian, 2014). The film and TV VFX industry is made up of over 500 companies (Curtin and Sanson, 2017), dispersed around the globe, servicing studios, streaming platforms and broadcasters that produce and deliver film and episodic content for audiences via the big and small screen[1].

Each VFX company has their own production pipeline – a complex environment of systems, technologies and processes that is always in a state of change and development. While particular commercial hardware and software choices are prevalent across the industry, many companies also create their own bespoke tools to perform a range of pipeline functions – ranging from object asset management, versioning and publishing; to generating realistic lighting and texture renders[2].

The objects generated from VFX pipelines encompass a range of digital file formats that often require specific software applications to open and read them. Alongside the production pipeline, sit multiple information systems, such as databases, code repositories, system logs and knowledge base websites (also known as wikis) that record information about particular projects, clients, crew and technologies.

The long-term preservation of digital VFX is a complex undertaking requiring planned strategies that will enable valuable assets and records to be accessible, understandable and readable into the future. To illustrate the complexity of the VFX production environments, this paper provides a real-world case study – a detailed examination of a single shot of a 3D animation short film project. It also draws from data I gathered over a two-year period, conducting interviews with over 20 professional VFX practitioners from different companies around the world. Additionally, the paper also presents a socio-technical analysis of the VFX production network, by applying actor-network theory (ANT).

1 I have used the term 'studio' in this paper to collectively mean film studios, streaming platforms and TV broadcasters.

2 For example see: https://www.fxguide.com/fxfeatured/a-glimpse-at-animal-logic/

# Background to the Case Study, Interviews and Socio-Technical Analysis Research Methods

## Bounty Hunter Shot pl_020: A 3D Animation Case Study

Animal Logic is an Australian animation and VFX company with offices in Sydney, Vancouver and Los Angeles. In 2016, Animal Logic partnered with the University of Technology Sydney (UTS) to create the Animal Logic Academy (ALA) – a professionally equipped studio, providing students with experiential learning in digital animation, VFX and immersive media. As part of their intensive, one-year Master of Animation and Visualisation (MAV) program, educators from UTS and Animal Logic, as well as mentors from the industry, provide students with a space to create, innovate and engage with emerging technologies.

During 2019, the MAV cohort was tasked to develop a 3D animated short film. The result was *Bounty Hunter* – a story about 'a middle-aged, overweight, intergalactic bounty hunter… on his last mission to catch and destroy the galaxy's biggest (and cutest) threat' (Animal Logic Academy, 2019).

**Figure 1.** Frame from the Bounty Hunter Trailer[3] featuring an alien worm character.

To produce Bounty Hunter, students at ALA used a range of industry-standard techniques, tools and software to generate six sequences, resulting in 42 animation shots. Overall, the animation project consisted of 4,005,235 files, equating to about 85 terabytes (TB) of data.

3 Bounty Hunter Trailer: https://youtu.be/4i5a4i6bhko

**Table 1.** Bounty Hunter sequences and shots.

| Sequence Code | Description | No. of Shots |
|---|---|---|
| pl | planet | 6 |
| cv | cave | 18 |
| br | cave broken | 12 |
| si | spaceship interior | 4 |
| se | spaceship exterior | 1 |
| end | end credits | 1 |

One of the shots of Bounty Hunter is, 'pl_020' (i.e. planet shot number two), which features the bounty hunter's spaceship landing over a blue alien worm (Figure 1). While only 160 frames long, this small shot of the project provides a good case study as it illustrates different kinds of VFX assets and multiple file types that were generated using up-to-date digital content creation (DCC) applications.

## Visual Effects Practitioner Interviews

From early 2018 to early 2020, I conducted a series of interviews with professional VFX practitioners working at international, award-winning companies and the VFX professional body located in Australasia, North America and the United Kingdom. I have spoken with 21 experienced VFX practitioners specialising in VFX production, technology, research and development, training, and information systems. I targeted a range of companies, both small and big, but focused on those that produced film and episodic content (i.e. not companies that exclusively produced VFX for commercials or extended reality projects[4]).

Most of the interviews were carried out face-to-face, with some facilitated via online video conferencing when it was not possible to travel. A standardised questionnaire was used; however, I conducted semi-structured style interviews so the interviewees could express their opinions more candidly. Each interview generally took about one hour. The interviews were audio-recorded then transcribed and analysed using constructivist grounded theory techniques including coding and memoing.

Grounded theory was adopted as it complemented my qualitative research approach, supporting 'the discovery of theory from data systematically obtained from social research' (Glaser and Strauss, 1967). I selected to use the constructivist form of grounded theory championed by Charmaz (2000), as it recognises that theory is not derived objectively from the data but can be shaped by shared experiences and relationships with participants and other sources of data (such as literature).

## Actor–Network Theory: Socio–Technical Analysis of the VFX Production Network

Drawing from both information systems and media studies approaches (Alexander and Silvis, 2014; Spöhrer, 2019), this research applied ANT to understand all the entities at play within the film and TV VFX production network. ANT is a form of social theory that was devised in the 1980s, principally by French sociologists Michael Callon and Bruno Latour and British sociologist John Law (Spöhrer, 2019). To describe the elements

4 Extended Reality, or 'XR' is an umbrella term for immersive media forms including Augmented Reality (AR), Virtual Reality (VR) and Mixed Reality (MR).

of socio-technical networks under examination, the term "actor" or "actant" is used in ANT to mean human as well as non-human entities.

Using 'VFX Assets and Records' as a focal point, I then mapped all the actors that play a role in the generation, management and preservation of digital VFX assets and records (see Figure 6). Because ANT asserts that social networks are heterogeneous, that is, made up of patterns of various (not merely human) materials; applying this thinking allowed me to investigate both technical and social elements of VFX production. As a result, the actors I identified include human actors and organisations such as 'VFX Artists' and 'VFX Companies', as well as inanimate things such as 'Storage Technology'.

I then drew up the intersections and translations[5] of the actors and highlighted those particular actors that I felt affected digital preservation the most. Then I explored in detail all the translations that occur with the actors with the most influence over the digital preservation outcomes for VFX records and assets.

## Understanding pl_020: The Objects and Production Environment of the Alien Worm Shot

A key application used by ALA and many VFX companies is Shotgun[6] – a cloud-based review and production tracking application. An examination of the Bounty Hunter project in Shotgun reveals that pl_020 has ten key assets (see Figure 2).

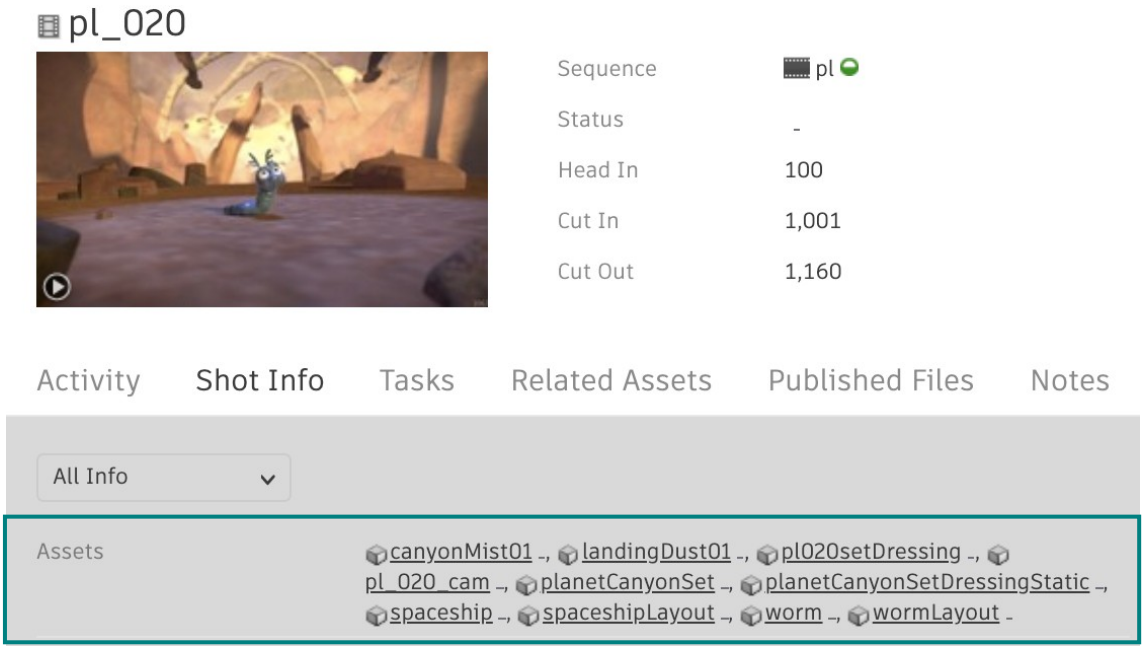


**Figure 2.** Screen capture of pl_020 shot information and assets from Shotgun.

5 Translation is an ANT term used to describe interactions or transactions between actors.

6 Shotgun Software: https://www.shotgunsoftware.com/

**Table 2.** Worm character tasks and file types.

| Task | File Extension | Description |
|---|---|---|
| Concept art | .PSD | Photoshop Document |
| | .PNG | Portable Network Graphic |
| Animation | .MA | Autodesk Maya Project |
| Modelling | .MB | Autodesk Maya Binary |
| Rigging | .FBX | Autodesk FBX Interchange |
| | .USD | Universal Scene Description |
| Lighting | .KATANA | Foundry Katana |
| Look dev. | .SPP | Adobe Substance |
| Surfacing | | |

Inspection of the 'worm' asset in Shotgun reveals that the students at ALA undertook multiple tasks ranging from concept art, to character lighting and surfacing. For each of these tasks, students used current professional DCC applications including the Autodesk Maya[7] 3D tool (Figure 3), Foundry's Katana[8] lighting and surfacing tool, Adobe Photoshop[9] image creation and editing tool, and Adobe Substance 3D[10] painter tool (Figure 4) to bring the alien worm character to life (see Table 2).

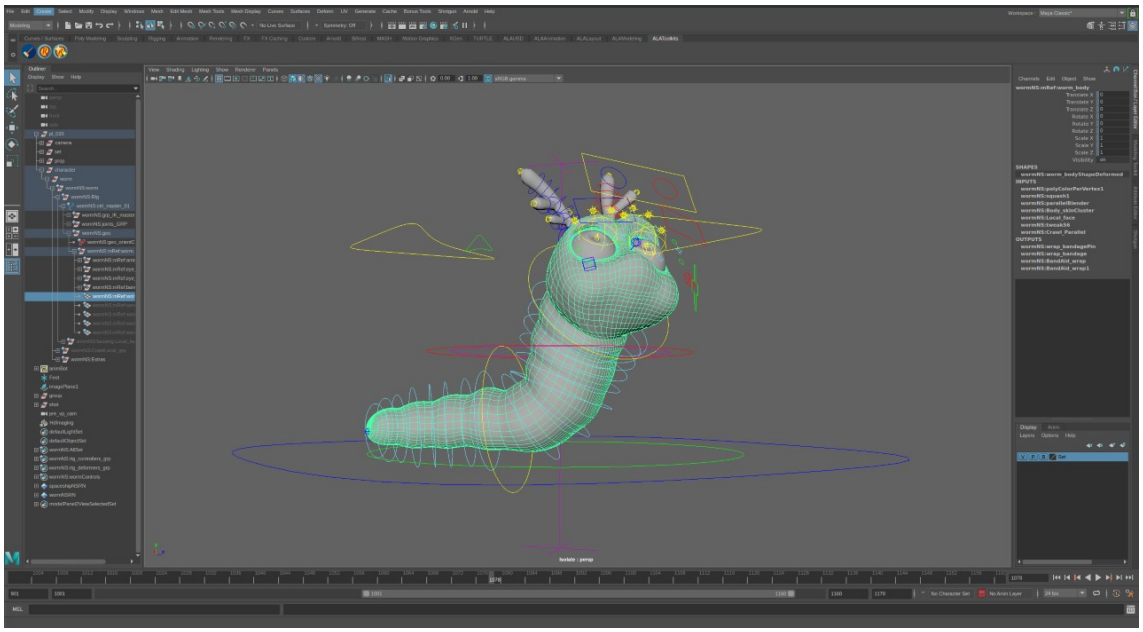

**Figure 3.** Worm character animation rig in Autodesk Maya.

7 Autodesk Maya: https://www.autodesk.com/products/maya/overview
8 Katana: https://www.foundry.com/products/katana
9 Adobe Photoshop: https://www.adobe.com/au/products/photoshop.html
10 Adobe Substance 3D: https://www.substance3d.com/

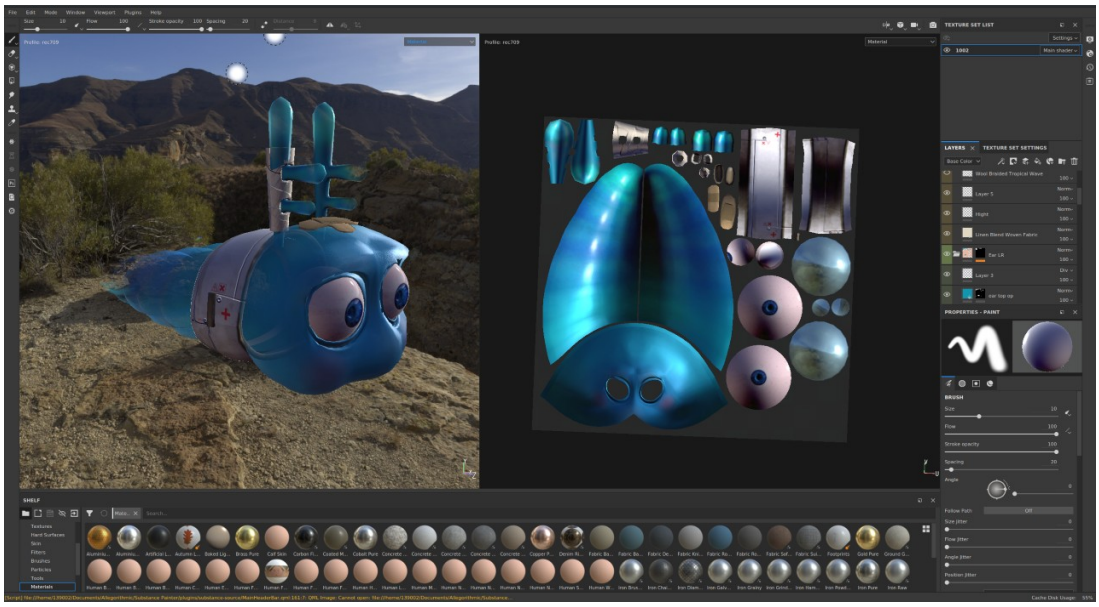

**Figure 4.** Worm character surfacing in Adobe Substance.

In addition to the alien worm character, shot pl_020 also features assets associated with the planet environment, the spaceship, and a virtual camera. While only the final published versions of assets are featured in the Bounty Hunter film, multiple versions of each asset were made during the course of production.

However, not only object assets were made during the production of Bounty Hunter, a complex mix of digital records were also generated:

- sequences and shots were composited, edited and output as high-quality, compressed codec ProRes 422 .MOV video files for review and feedback;
- assets, tasks, shots and sequences were logged and tracked using Shotgun;
- training guides and tips were shared via wiki pages;
- day-to-day announcements and production information was disseminated via Slack[11];
- pipeline and technology tools and code were maintained and updated using various platforms and online code repositories; and
- administration records were created and maintained in Google Drive and Content Manager[12].

See Figure 5 below for a graphical representation of the various assets, records and data sets created during Bounty Hunter production.

11 Slack: https://slack.com/intl/en-au/
12 Content Manager: https://www.microfocus.com/en-us/products/enterprise-content-management/overview

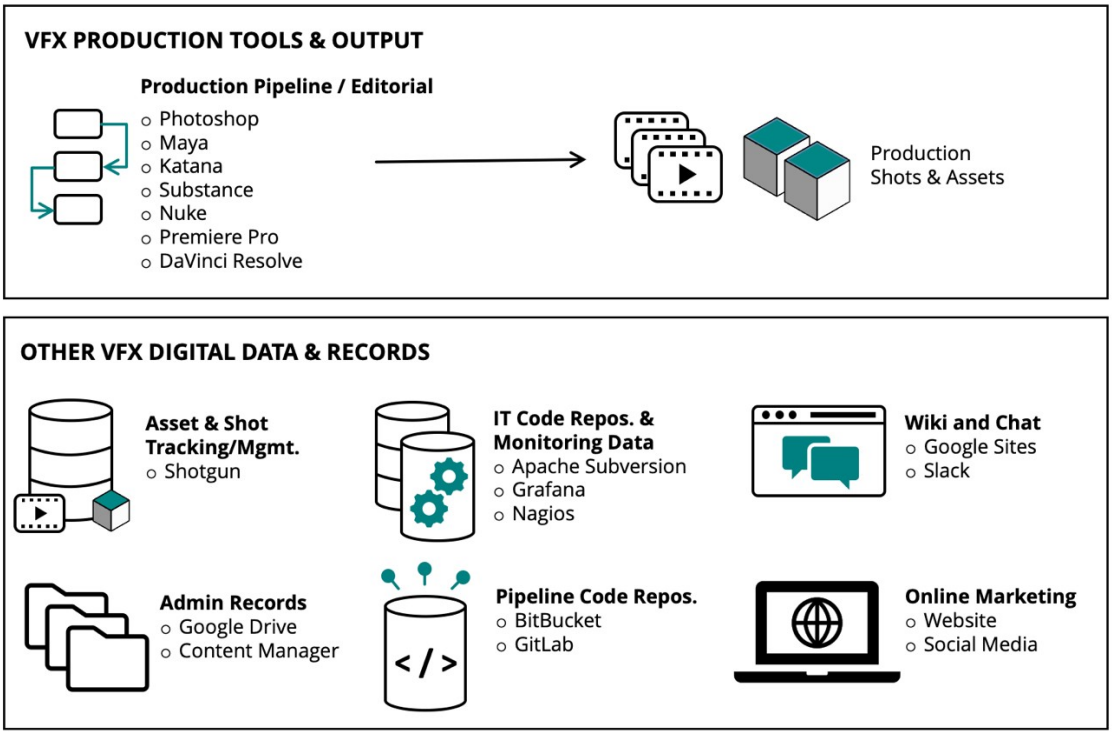


**Figure 5.** Assets, data and records created during Bounty Hunter production.

## Challenges and Strategies for Preserving VFX

While Bounty Hunter is a student project, as the case study demonstrates, the students at ALA produced an industry-standard short film. They utilised professional production and DCC software and generated assets and shots output to a variety of proprietary file formats. They also created a range of other records and data sets, housed within code repositories, databases and various online platforms – all of which reflect modern VFX production environments.

Digitally preserving Bounty Hunter and other types of VFX projects is very challenging. As Corrado and Sandy (2017) aptly note, digital preservation 'is not about backups and recovery, it is not just about having access to content, and it is not an afterthought'. Instead it is a management issue that, for VFX, requires navigating a very complex network.

### Actors and Preservation Challenges in the VFX Production Network

As Figure 6 illustrates, there are many actors that play a role in the generation, management and preservation of digital VFX assets and records.

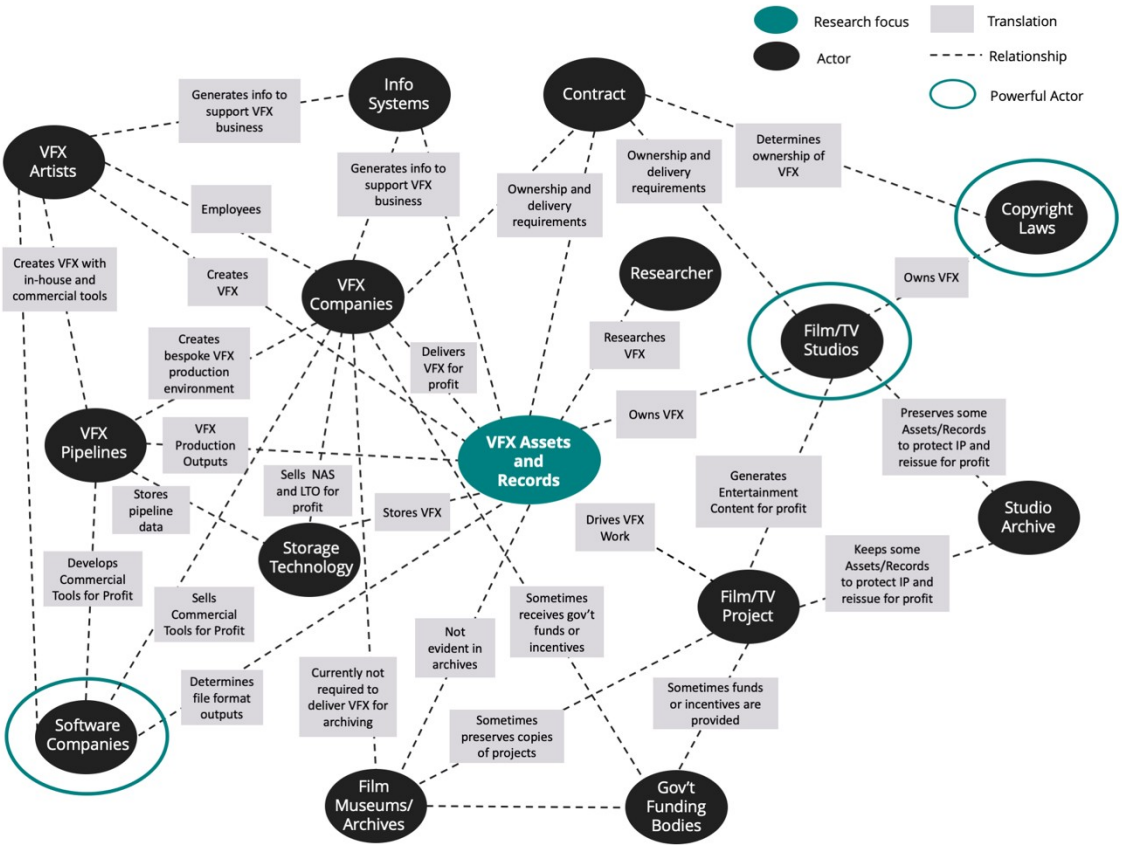


**Figure 6.** VFX production assets and records socio-technical network.

I have highlighted 'Copyright Laws', 'Film/TV Studios' and 'Software Companies' as key influencing actors in the network. The power that these actors hold within the industry has directly affected the ability of VFX Artists, VFX Companies and Film Archives/Museums to preserve VFX records and assets over time. Table 3 below provides a breakdown of these powerful actors, investigates their translations in more detail and outlines resulting preservation implications.

**Table 3.** Powerful actors in the VFX production network.

| Actor | Description | Translations | Preservation Implications |
|---|---|---|---|
| Copyright Laws | Legislation of country that produces film/TV projects | Determines Studio/Production Company as the owner of the project, VFX Company work is "work made for hire" (Copyright Act of 1976 (USA), §101).<br>For work made for hire projects, copyright persists for 120 years after creation or 95 years after publication, whichever is shorter (Copyright Act of 1976 (USA), §302).<br>VFX Contracts support | Restricts ownership and use to the Studios. Access is not available for many decades. Reduces chances of Film Museums/Archives to acquire project material close to creation. Digital preservation is harder to achieve. |

| | | | |
|---|---|---|---|
| | | Copyright Law terms. | |
| Film/TV Studios | Production and distribution company that produces film/TV projects for profit | Preserves some VFX content to protect their IP. Mainly preserves final film to be able to re-distribute and sell for profit.<br>Creates VFX Contracts that support their sole ownership. Contracts allow VFX Companies and VFX Artists to use some material to promote themselves, e.g. for showreels. This only is permitted after the film/TV project is released.<br>Determines security requirements for VFX Companies and VFX Pipelines to ensure IP is protected. | If Studio does not keep VFX long term, it will become lost over time. Studios do not include archiving or preservation requirements in VFX Contracts. Standardised formats and asset types should be stipulated to support preservation. Studio's strict security requirements sometimes requires all VFX materials to be deleted out of VFX Company environments after delivery. VFX records/assets become lost forever. |
| Software Companies | Develops DCC applications for VFX | Sells their products to VFX Companies for profit.<br><br>Determines available file formats and backwards compatibility for application files. | Sometimes software pricing and availability restricts VFX Companies from being able to open and read older VFX assets. Preservation becomes harder if there is no backwards compatibility and support for open formats. |

To achieve effective and consistent preservation in the industry, negotiations with all of the actors (not just the powerful actors) will be required. Additionally, specific strategies will need to be developed to deal with large volumes (and dispersion) of digital files, and the technology change and dependencies prevalent in VFX production.

## Too Much Data Everywhere

As a VFX technical specialist revealed to me during an interview in 2018, a full-CG feature film project his company was working on at the time, produced a staggering 1.5 petabytes of data per day during peak production (personal communication, March 2018). Additionally, to meet disaster recovery needs, two copies of this data was written to Linear Tape-Open (LTO) magnetic data tapes daily; one copy for on-site storage, and one for off-site storage. Although not all VFX companies produce volumes as high as this example, they all produce comparatively large amounts of data to manage.

Given there is a digital deluge generated for every project, as soon as production ends and the client receives the final shots, VFX companies swiftly transfer project data offline to make room for the next project. Generally, only pipeline assets and editorial content is migrated (or as the VFX data people like to say, "archived") to tape for long-term storage. For larger companies, decisions are made about which versions to keep and which can be deleted. Usually, the latest versions of assets, plus their dependencies (i.e. the corresponding files that make up the assets) and important versions of shots are

chosen to be kept long-term on LTO. For smaller companies (including studios like ALA), often everything is retained and moved to second-tier network attached storage (NAS) or LTO. Disappointingly, none of the VFX companies I examined had any plans to implement digital repositories for their long-term storage. Instead, everyone continues to use LTO due to its comparative low-cost.

Another challenge for preservation is that sometimes only a limited amount of data is allowed to be retained by the VFX company. This is because, technically, the client is the owner and copyright holder of the assets created for a film or TV project. They are legally allowed to order all of the VFX project assets to be deleted after a project ends. Unfortunately, there is no consistency with retention requirements, as one interviewee said to me, the guidelines 'are different per studio and also different per project' (personal communication, March 2019).

While asset and shot version selection has its merits, VFX companies do not carry out holistic appraisal, selection and disposal activities across all of their digital data. Pipeline outputs are preferenced, despite the fact that assets become obsolete rather quickly. Remaining records are generally maintained over time in their native systems or sometimes migrated to newer systems once the older ones are decommissioned.

For example, when I questioned practitioners about archiving their wiki pages, they said it was something that they never considered. Usually pages are sustained over time, or simply unpublished or deleted when their currency diminishes. This is a shame as valuable information about the process of VFX production is captured in wikis, including training videos and guides about particular tools and procedures for each project. Archiving this material provides a valuable corporate history and insight into VFX production trends and techniques over time. Furthermore, there are established processes and formats available for web archiving[13] as opposed to archiving VFX asset files.

Ideally, VFX companies should appraise all of their digital collections – not just the final production outputs – and determine their short-term and long-term value. Then they can dispose of short-term, low-value assets and records and allocate resources, such as storage requirements[14], accordingly. Thus, designating the long-term preservation activities towards the assets and records that have value.

## Rapid Technology Changes and Dependencies on Proprietary Software

VFX production is always evolving and operating 'on the frontiers of new technology' (Charisse, 2014). Meaning that pipelines are in a constant state of change and the software alters from project to project – making it difficult to open and read assets as time goes by. For example, when discussing a decade-old project with a practitioner, it became clear that assets from the project were no longer usable:

> '[T]he geometry cache that we would have used back then is a proprietary caching format that we don't use any more. The rigs… the character rigs that we used were done in Softimage, which is end life – nobody uses it

13 For example, see this resource from the Digital Preservation Coalition: https://www.dpconline.org/handbook/content-specific-preservation/web-archiving

14 Interestingly, while LTO storage is the industry standard, I was surprised to learn that many companies do not have tape migration plans in place to deal with the fact that LTO drives are only two-generation backwards compatible.

> anymore… the UVs[15] were done in a proprietary format, which we've changed subsequently… And the renderer that we used to render the characters has changed… [A]side from our ability to actually load up the geometry in our old format and convert it to a new bit of geometry, they're effectively useless…' (personal communication, March 2018).

While emulation could be seen as a viable strategy, given the array of software used in VFX, an extremely large number of commercial and bespoke applications with their multiple versions would need to be preserved and available via emulation platforms. In addition, an emulation strategy would come up against copyright issues:

> 'Software is typically covered by copyright. In order to make copies of software for preservation and to provide access, the institution needs to be able to do so legally' (Corrado and Sandy, 2017).

Because VFX companies often develop their own software, tracking down and gaining copies of their tools (plus the required permissions) would be a complicated endeavour. However, emulation, could be achievable through the development and use of common, standardised formats which could be read by a smaller number of attainable software applications.

Additionally, through the development and adoption of standard formats, another approach – the development of universal file viewers – becomes more feasible. As a recent 3D and virtual reality data curation study revealed, 3D data experts are expressing a need for universal, open source viewers that support 'streaming and annotation on archival formats of 3D models and makes archival master files accessible' (Hall et al., 2019).

Discussion with VFX practitioners revealed that presently, no transformation activities are undertaken before archiving. Instead, archived files remain in their original formats, often destined for obsolescence. However, the industry has made efforts to develop more open and ubiquitous file formats for use *during* production. Over the years, this work was often independently led by individual VFX companies, and more recently, organisations including the Academy Software Foundation[16] and the VFX Reference Platform[17] have been established to coordinate and disseminate new open formats for the VFX and wider media industries.

An early example is the OpenEXR format developed by Industrial Light and Magic (ILM), first released in 2003 (Lucasfilm, 2020). "OpenEXR is an open-source high-dynamic-range floating-point image file format for high-quality image processing and storage" (Kainz et al., 2020). The format was designed to meet high colour fidelity needs of the VFX industry (namely for compositing) and uses data compression to reduce image file size.

More recently, in 2011 Sony Pictures Imageworks and ILM produced the Alembic format which focused on the interchange of 3D model geometries (Variety, 2011). Using Alembic reduces disk storage requirements, as it 'bakes in' complex digital geometric construction data such as polygon meshes and particles into an extensible format that is supported by common VFX tools (Lucasfilm and Sony Imageworks, 2020).

15 A UV is a mapping method used to "wrap" a 2D image texture onto the structural build (also known as the polygon mesh) of a 3D model.

16 Academy Software Foundation: https://www.aswf.io/

17 VFX Reference Platform: https://vfxplatform.com/

Also, during 2016, Pixar Animation Studios undertook an open-source release of their Universal Scene Description (USD) framework. Essentially USD is a common format, using hierarchically organized, static and time-sampled data. It can be used by various DCC applications to support the interchange and augmentation of 3D scenes composed of elemental assets (e.g. models) or animations (Pixar Animation Studios, 2017). Since its release, it has been adopted widely across industry pipelines – including the UTS ALA pipeline.

The use of common formats such as OpenEXR, Alembic and USD means that motion picture image files and 3D geometries can be read by multiple types and versions of software, some of which could be featured in emulation platforms. Or perhaps, universal file viewers could be developed to read common formats – providing a viable way to keep some VFX files usable over time. Stipulating these common types of formats for archiving and delivery with the final shots in VFX contracts may also help ensure the ongoing digital preservation of some key VFX assets into the future.

However, as indicated in the case study, VFX production encompasses a variety of format types – much more than image files and 3D model geometries. Therefore, further work will be required to determine ways in which more complicated VFX assets or potentially representations of them, can be preserved. For instance, a turntable version of a complex 3D model and some breakdown material could be a sufficient method to preserve evidence of the design, lighting and surfacing of a model, without having to preserve all the original DCC application files[18].

## Conclusion

This paper has outlined some of the key challenges and strategies as to how the VFX industry can preserve digital production assets and records. Through a detailed examination of Bounty Hunter – a 3D animation short film produced by students of the Animal Logic Academy – data gathered via a series of interviews conducted with professional VFX practitioners, and actor-network theory socio-technical analysis of VFX production networks, I have presented the complexities of digital VFX assets, records and production environments.

The film and TV VFX industry is in a constant state of technological flux, developing and improving tools and adopting new applications to deliver even-more impressive spectacles to audiences. For every project, mammoth quantities of digital data is generated, encompassing files in a range of formats that depend upon DCC proprietary applications. Despite these significant challenges, the VFX industry has already introduced open, standardised formats for production including OpenEXR, Alembic and USD. Once adopted throughout VFX pipelines, formats such as these could prove effective for long-term digital preservation including emulation or universal viewer approaches. In addition, by widening the focus from pipeline outputs (assets and shots) to all digital VFX collections (wikis, production tracking databases, marketing materials, code repositories, etc.), the industry can take holistic steps to appraise and understand the value of their digital assets and records.

Through such strategies, I hope the industry will begin to futureproof their work, so that evidence of this exciting, creative and technical field of film and TV production will be available, understandable and usable over time.

18 See this example from ArtStation: https://www.artstation.com/artwork/EdEn0

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## References

Alexander, P. & Silvis, E. (2014). Actor-network theory in information systems research, *Information Research*, 19(2). Retrieved from http://informationr.net/ir/19-2/paper617.html

Animal Logic Academy. (2019). *Bounty Hunter*. Retrieved from https://animallogicacademy.uts.edu.au/project/bounty-hunter/

Charmaz, K. (2000). Grounded theory: Objectivist and constructivist methods. In N.K. Denzin & Y. Lincoln (Eds.), *Handbook of qualitative research*, (pp. 509–536), Thousand Oaks: Sage Publications.

Charisse, P. (2014). Archiving software and content in visual film effects: An insider's perspective. In J. Delve and D. Anderson (Eds.), *Preserving complex digital objects*, (pp. 291–295), London: Facet.

Copyright Act of 1976 (USA), §101, §302. Retrieved from https://www.copyright.gov/title17/title17.pdf

Corrado, E.M. & Sandy, H.M. (2017). *Digital preservation for libraries, archives, and museums* (2nd ed.), Lanham: Rowman and Littlefield.

Curtin, M. & Sanson, K. (2017). Fringe city: Editors' introduction. In M. Curtin and K. Sanson (Eds.), *Voices of labor: Creativity, craft, and conflict in global Hollywood*, (pp. 200–203), Oakland: University of California Press.

Glaser, B.G. & Strauss, A.L. (1967). *The discovery of grounded theory: Strategies for qualitative theory*, New Brunswick: Aldine Transaction.

Hall, N.F., Hardesty, J., Lischer-Katz, Z., Johnson, J., Cook, M., Griffin, J., Ogier, A., Carlisle, T., Xie, Z., McDonald, R. & Wittenberg, J. (2019). Challenges and directions in 3D and VR data curation. *International Journal of Digital Curation*, 14(1). doi:10.2218/ijdc.v14i1.588

Kainz, F., Bogart, R., Stanczyk, P. & Hillman, P. (2013). Technical Introduction to OpenEXR. Retrieved from https://www.openexr.com/documentation/TechnicalIntroduction.pdf

Lucas, G. (1977). *Star Wars*. Lucas Film/20th Century Fox.

Lucasfilm. (2020). *OpenEXR*. Retrieved from https://www.openexr.com/

Lucasfilm & Sony Imageworks. (2020). *Alembic*. Retrieved from https://www.alembic.io/

Pixar Animation Studios. (2017). *Introduction to USD*. Retrieved from https://graphics.pixar.com/usd/docs/index.html

Rüling, C.C. & Duymedjian, R. (2014). Digital bricolage: Resources and coordination in the production of digital visual effects. *Technological Forecasting and Social Change*, 83, 98–110. doi:10.1016/j.techfore.2013.05.003

Scott, R. (1979). *Alien*. 20th Century Fox/Brandywine Productions.

Spöhrer, M. (2019). Applying actor-network theory in media studies: Theoretical (im)possibilities. In M. Spöhrer (Ed.), *Analytical frameworks, applications, and impacts of ICT and actor-network theory*, (pp. 1–27), Hershey: IGI Global. doi:10.4018/978-1-5225-7027-1.ch001

Variety. (2011, August 9). ILM, Sony Imageworks release Alembic 1.0, *Variety*. Retrieved from https://variety.com/2011/digital/news/ilm-sony-imageworks-release-alembic-1-0-1118041083/

Venkatasawmy, R. (2013). *The Digitization of cinematic visual effects: Hollywood's coming of age*, Plymouth: Lexington Books.

Wise, R. (1979). *Star Trek: The Motion Picture*. Paramount Pictures.