The Data2Dome Project

— A consolidated, data-driven content distribution system

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Fig. 1: The Data2Dome logo.

Contents

Astronomy is a dynamic discipline. New press releases, images, videos and data are being published every day. However, this flow of exciting new content is typically not integrated in planetariums: rather than bringing the latest science into the dome hours or even minutes after it is published, new data is typically presented days or even weeks later — and often not at all given the many barriers to getting them into the dome. As a result, the planetarium, usually seen as the local centre of astronomy competence, lags behind blogs, newspapers, TV and other media. The Data2Dome (D2D) project is aimed at streamlining the flow of content from research institutions to planetariums, offering audiences a unique opportunity to access the latest data from space in near real time.

Rationale

Space science and astronomy are attractive subjects to both students and the general public. Contact with these subjects has a positive effect on students' interest in science and scientific careers, and on public support for science and technology. In addition, the importance of science museums to scientific learning is well known. Museums are among the main sources that people rely upon for learning about science and technology (Falk, 2007).

Planetariums are important venues where the public can get excited about science and as learning environments they have a proven advantage over classrooms and other venues. Yu et al. (2015, 2016) found that immersion in a dome theatre leads to greater learning in university students. The wide field of view reduces the cognitive load for spatial understanding, and the stimulation of the peripheral vision leads to greater attention.

Looking at estimated annual attendance figures for planetariums around the world (school shows, public shows, concerts, laser shows, counted together) reveals some striking numbers. It is estimated that in 2015, up to 123 million people visited the 4105 planetariums around the world (Loch Ness Productions, 2015)[1]. And this number may be on the increase (for comparison in 1995, an estimated 75 million people visited the then existing 2613 planetariums around the world).

Not only is attendance high, but planetariums are also among the science-related activities and attractions that people would most like to visit. A study conducted in the UK reported that one in five (20%) UK citizens had an interest in visiting a planetarium, which contrasted with 12% who expressed an interest in visiting a museum or a science centre (Mori, 2005). Nevertheless, when compared with attendance at other cultural institutions such as public libraries, art museums or zoos/aquariums, attendance at science/technology museums ranks lower (National Science Board,

[1] Estimated numbers are only based on visitors' attendance at 10% of the world's domes (independent of dome size), so the extrapolation to a global attendance estimate should be done with caution.

2014)[2]. For example, 27% of Europeans visited a zoo/aquarium in 2005 whilst 16% visited a science and technology museum (European Commission, 2005).

From the visitor's point of view, an ideal exhibit is one that makes the subject come to life, can be quickly understood, and is memorable (Alt and Shaw, 1984). One way to achieve this in a planetarium is to communicate authentic science as soon as possible after it happens.

The Data2Dome (D2D) project[3] is aimed at streamlining the flow of content from research institutions to planetariums, offering audiences a unique opportunity to access the latest data from space in real time. Its innovative character makes possible the development of new, engaging ways of communicating complex topics with a global focus, compared to other methods of demonstration in planetariums. D2D can be a powerful tool to establish audience engagement as both a means of learning and a means of affecting relevant change in visitors' interest and appreciation for science. Ultimately we believe D2D will help attract broader audiences to the planetariums.

Several reasons have been identified for the delay between the availability of new science and its use in planetariums:

- **Manual work**: Bringing content into a planetarium system typically requires a significant amount of manual work with laborious content pipelines: copying content onto the system; distributing it to the render nodes; slicing; writing scripts to actually display the assets; and so on. Some planetariums, like Morrison Planetarium (see Tell, 2016) and Adler Planetarium (Subbarao, 2016) go to considerable lengths to collaborate with scientists on presentations that involve importing and visualising research data. These are, however, one-off events that take days if not weeks of manual work, and except for the Domecasting in Uniview that Adler Planetarium offers on occasion, they are not easily shared with the community.
- **Content import not standardised**: The pipelines and work procedures for importing content are typically very vendor-specific, resulting in difficulties with delivering content across the system boundaries in an easy and seamless way.
- **Lack of consolidated data access**: Astronomical data on the internet are usually distributed across many different research institutions' websites. As a result, it is not easily found and easily escapes the attention of a planetarium operator.
- **Lack of connectivity**: Planetarium systems might not be connected to the web, because of, for example, security or performance concerns.
- **Content is not well-served**: The planetarium operator has to gather background information concerning a particular data item, such as a newly published image, or tabular data. The learning curve for the operator may be steep, or the operator might simply not have time to read a comprehensive scientific paper that describes the data product.

[2] Acknowledging that planetarium domes are not always attached to science museums.
[3] http://www.eso.org/d2d

Philosophy

The philosophy of the D2D project relies on a combination of **staff curation of assets** (the model used by American Museum of Natural History's Digital Universe, see Abbott et al. 2004) as well as **crowd-curation** plus a ranking system on the side of the vendors. It also relies on **distribution** via the Internet, on **standardisation** of formats and process, and on consolidation of data or metadata in online **databases**. The project is partly arising from the efforts of the IPS Science & Data Visualization Task Force[4]. The European Southern Observatory (ESO), ESA/Hubble, Adler Planetarium, Planetarium Münster and Planetarium am Insulaner, Berlin have pledged resources to implement D2D.

The Data2Dome webpage will be the central point of contact for the project: http://www.eso.org/d2d

Vision

D2D is a system whereby astronomy data is seamlessly integrated with today's real-time fulldome planetarium systems. Content, and metadata describing it, are fed via a reasonably fast Internet connection (at least 10-20 Mbit/s) into the planetarium system automatically, significantly reducing the workload for the planetarium operator.

Every morning, planetarium presenters around the world will be able to access a menu that will allow them to select interesting news and fresh datasets — news, sky event data, historical event data and more (see the use cases below) — and mark up the full datasets and metadata for download, for possible inclusion in show segments during the day. Some of these items may be under embargo and will only be shown when they are public. In some sense the presenter can be seen as an "Astronomical Weatherman" being able to report on fresh events almost as they take place.

Data

The system will be capable of sharing the following standard asset types:

- Descriptive **metadata** as support for the presenter: concise, well-written descriptions of the content; credits; license; embargo date; links to more information etc. for the planetarium lecturer. this will probably be written in English but can be translated with machine-translation and further improved through crowd-translation. The Astronomy Visualization Metadata Standard (AVM, Christensen, 2005, Hurt et al., 2007) has been chosen for this. This standard describes metadata tags in the header of an image file containing information such as position, orientation and size of the image on the sky, a popular description of the Content resource, credit information and the like.

[4] http://www.ips-planetarium.org/?page=visualization

- **Flat videos**
- **Flat images**, including planetary maps, images of sky objects, all-sky panoramas/fulldome images
- **Fulldome videos**
- **Audio**, including interview clips, sounds, music
- **Show sequences,** including presentation metadata

Example use cases

The following are use cases which are currently being implemented by Content Providers. The number of events is the number of data items that are available at launch. The increment per year means the number of new data items added per use case per year.

A new press release

1. An Earth-like extrasolar planet is announced by NASA.
2. Within hours a human curator finds the press release interesting and features it.
3. The D2D JSON file is automatically updated within minutes to contain the new press release metadata.
4. Soon after (to be determined by the vendor) the news will appear in the the D2D presenter menu under News.
5. The release has the necessary metadata to characterise the content, and points to data/high-res assets (at least an image).
6. A lecturer thinks this is relevant news, flies to the host star in the planetarium system, downloads assets and presents them to the audience.

Number of events: —
Increment per year: 3500
Implementation: This use case will be implemented by the *Portal to the Universe*[5] (PTTU) module of D2D (PTTU is a Content Provider, a project sponsored by ESO, ESA/Hubble and the IAU). Press releases from all astronomy and space organisations are crawled and syndicated by PTTU.

Regularly updated show sequence for a Solar System show

1. For a planetarium show about planets, a regular update segment will be developed by the producer, in the form of a realtime show sequence. This is then distributed and shown on different fulldome systems.
2. Presentation metadata tags are used to describe how the media of the update sequence should appear on the planetarium dome.

[5] http://portaltotheuniverse.org/

3. Using the D2D tools, the sequence package — data and a metadata file describing the sequence — are distributed to the planetariums.
4. The presenter picks the most recent update, downloads the data/highres assets and metadata file, and the local planetarium software automatically translates the presentation metadata into its native scripting language (or similar) and runs the sequence.

Number of events: —
Increment per year: 10-20
Implementation: The presentation metadata are planned to be implemented by LWL-Planetarium Münster (Björn Voss) and Planetarium am Insulaner, Berlin (Jürgen Rienow).

Sky event

1. Tonight is a lunar eclipse!
2. The event appears in the presenter menu.
3. As it is ranked highly the presenter bring this event up in today's Sky at Night shows. The associated assets (images, flat videos and fulldome videos) are downloaded, automatically distributed to all render nodes of the planetarium system and available for instant presentation. The lecturer is supplied with background information concerning the event, such as the times of key milestones.

Number of events: Around 600 (for the period 01.01.2017–31.12.2018)
Increment per year: 300
Implementation: This use case will be implemented by the *AstroCalendar* module of D2D. *AstroCalendar* is a project of ESO, for the ESO Supernova Planetarium & Visitor Centre[6] (a new planetarium at ESO's Headquarters in Garching bei München).

Historical event

1. It's 20 July .
2. The D2D menu highlights the anniversary of the Apollo 11 Moon landing.
3. The planetarium operator brings up this event in today's Sky at Night shows. The associated assets (images, all-sky images, flat videos and fulldome videos), are downloaded, automatically distributed to all render nodes of the planetarium system and available for instant presentation.The lecturer is supplied with background information concerning the Apollo 11 Moon landing.

Number of events: Around 300.
Increment per year: 5

[6] http://supernova.eso.org/

Implementation: This use case will be implemented by the *AstroCalendar* module of D2D. *AstroCalendar* is also a project of ESO, for the ESO Supernova.

The Chelyabinsk meteorite

1. An important event like the Chelyabinsk meteorite takes place.
2. It happens too fast for a press release to appear, but a blog contains a link to a high-res video of the Chelyabinsk event.
3. The D2D blog JSON file is automatically updated within minutes to contain the new press release metadata.
4. Soon after (to be determined by the vendor) the news will appear in the the D2D presenter menu under News.
5. Owing to its importance and topicality the asset soars in the ranking.
6. It is quickly discovered by presenters worldwide.
7. The asset is displayed on domes worldwide hours after the event.

Number of events: a few.
Increment per year: a few
Implementation: This use case will also be implemented by the Portal to the Universe module of D2D (blogs can also be featured in D2D).

HST images

1. The presenter needs an image of the interesting Wolf-Rayet object WR 124.
2. He/she searches the metadata in the Vendor Cloud, and finds a Hubble image[7].
3. The 3.8 MB 1300-pixel image data[8] are marked for download and are displayed on the dome after a few seconds.

Number of items: Around 5000
Increment per year: Around 200.
Implementation: This use case will be implemented by ESA/Hubble for ESA.

ESO images

1. The presenter needs an image of the interesting Flame Nebula.
2. He/she searches the metadata in the Vendor Cloud, and finds an ESO image[9].
3. The 145 MB 7000 x 9000-pixel image data[10] are marked for download and are displayed on the dome after a few minutes.

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[7] https://www.spacetelescope.org/images/potw1533a/
[8] Downloaded directly from https://www.spacetelescope.org/static/archives/images/original/potw1533a.tif
[9] http://www.eso.org/public/images/eso0949a/
[10] Downloaded directly from http://www.eso.org/public/archives/images/original/eso0949a.tif

Number of items: Around 11,000
Increment per year: Around 600.
Implementation: This use case will be implemented by ESO.

NASA Wise

http://astropix.ipac.caltech.edu/link/91?format=json

NASA GALEX

http://astropix.ipac.caltech.edu/link/5qb?format=json

NASA Chandra

http://astropix.ipac.caltech.edu/link/gl?format=json

ESA Herschel (via IPAC)

http://astropix.ipac.caltech.edu/link/5q8?format=json

NASA NuSTAR

http://astropix.ipac.caltech.edu/link/1rt?format=json

NASA Spitzer

http://astropix.ipac.caltech.edu/link/45?format=json
(give it time to load)

ESO videos (flat and fulldome)

1. The presenter needs a video of a 3D flyaround of a globular cluster.
2. He/she searches the metadata in the Vendor Cloud, and finds a ESO fulldome video[11].
3. The 9.4 GB 4k-frames data package[12] is marked for download and are displayed on the dome after a few hours.

Number of items: Around 3000

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[11] http://www.eso.org/public/videos/globularcluster/
[12] Downloaded directly from https://media.eso.org/public/archives/videos/dome_4kmaster/globularcluster.zip

Increment per year: Around 150.
Implementation: This use case will be implemented by ESO.

Hubble videos (flat and fulldome)

1. The presenter needs a video of the super-Earth 55 Cancri e.
2. He/she searches the metadata in the Vendor Cloud, and finds a Hubble flat UHD video[13].
3. The 100 MB Ultra HD H.265 frames data package[14] is marked for download and is displayed on the dome after a few minutes.

Number of items: Around 1100
Increment per year: Around 50.
Implementation: This use case will be implemented by ESA/Hubble for ESA.

ALMA, ESO Webcams and Live Observing

1. The presenter needs to show what a research telescope is doing right now.
2. He/she shows the ALMA or ESO Paranal webcams (full 4k fulldome resolution).
3. He/she turns on the overlays on the webcam images showing where the telescopes observe. Similar to http://www.ls.eso.org/lasilla/dimm/lasc/ or even a DSS or SDSS image of the location like https://twitter.com/hubble_live
4. He/she may even show the actual proposals being carried out (in text form).

Number of items: A few
Increment per year: Around 365 x 24.
Implementation: This use case will be implemented by ESO for ALMA and ESO.

ESO Music Archive

5. The presenter needs to play some Creative Commons music suitable for planetariums.
6. He/she consults the ESO Music Archive, plays back some previews and downloads what's needed in high quality.

Number of items: 400
Increment per year: 100
Implementation: This use case will be implemented by ESO.

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[13] http://www.spacetelescope.org/videos/heic1603a/
[14] Downloaded directly from http://www.spacetelescope.org/static/archives/videos/ultra_hd_h265/heic1603a.mp4

3D Models

Implementation

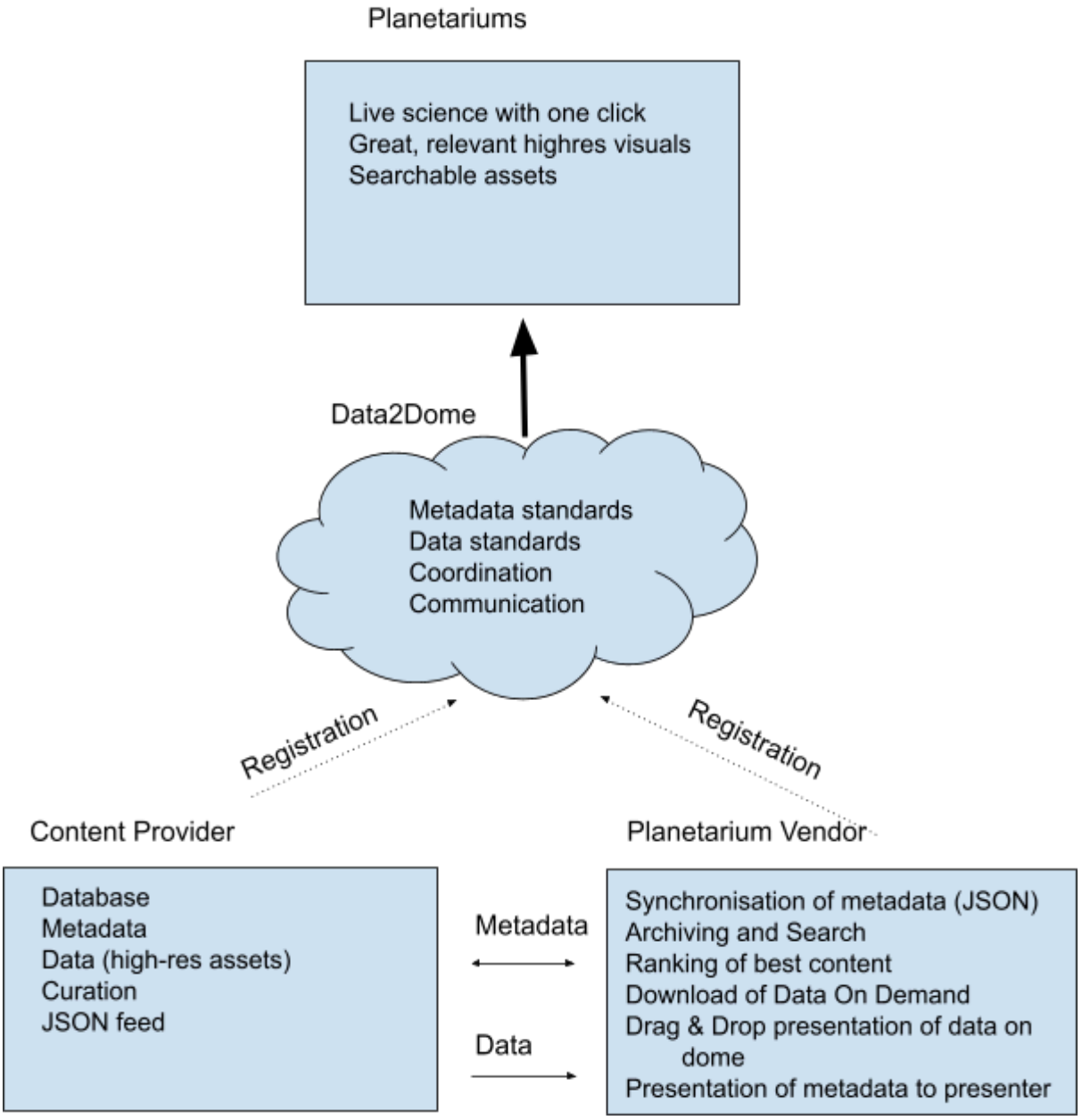

Fig. 2: Block diagram of the Data2Dome *system.*

The **D2D project** determines the standard of the metadata (AVM), the format for the exchange of the metadata (JSON) and data and approves the Content Providers. D2D also communicates any changes to the standards and new Content Providers with all stakeholders.

The **Content Provider** maintains a database of metadata and data. The Content Providers must guarantee that data and metadata are free to use by the planetariums (preferably under a Creative Commons Attribution licence; see Davies & Christensen, 2016). This content will need to be curated so that the best (most relevant and most interesting) data are provided. The metadata are made available in a JSON file. Example Content Providers are: ESO, NASA Spitzer, NASA Chandra, NASA/ESA Hubble, Gemini, Keck, Keck, ESA, NOAO, NRAO, NAOJ, NASA.

The **Planetarium Vendor** will (through a Vendor Cloud solution) synchronise the JSON file as often as necessary, provide an interface that allows the presenter to search and filter the metadata instantaneously, and then download the presenter's chosen asset on demand in any size needed (the JSON file has deep links for different format/sizes). The metadata are archived and ranked so that the best content is most visible at any given time. The data assets are automatically sent to the render nodes, sliced if necessary, and installed at the appropriate location for easy display (at the default location of the dome, i.e., the "sweet spot", with the default size if not specified otherwise). The planetarium presenter is also offered a text summarising the content on a console screen. Example Planetarium Vendors are: Digistar/E&S, Dark Matter/Sky-Skan, Uniview/Sciss, Powerdome/Zeiss, SkyExplorer/RSA Cosmos, Mitaka/NAOJ, OpenSpace, World Wide Telescope/AAS.

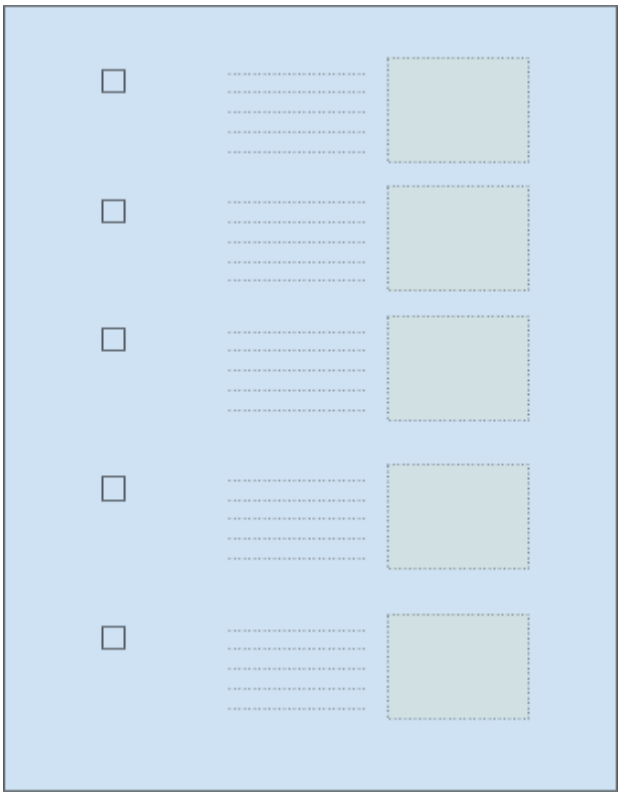

Fig. 3: The presenter is shown a menu from which to chose data in the planetarium system, created by each vendor, based on the metadata synchronised from the Content Provider's JSON feed.

Conclusion

Space science and astronomy are attractive subjects to both students and the general public. Planetariums are important venues where the public can get excited about science and as learning environments they have a proven advantage over classrooms and other venues. One way to make the subject of astronomy come to life in a planetarium is to communicate authentic science as soon as possible after it happens. The D2D project is aimed at streamlining the flow of content from research institutions to planetariums, offering audiences a unique opportunity to access the latest data from space in real time.

Several use cases are being implemented, by Content Providers such as ESO, ESA/Hubble, Adler Planetarium, Planetarium Münster and Planetarium am Insulaner, Berlin.

In the medium-term, presentation metadata could be added with indications of how the data/high-res assets should be presented. This would be most useful for news items involving multiple images or media, e.g. crossfades of images of the same object at different wavelengths, at different times, or simply side-by-side arrangements of images that are related to each other. Another example would be the astronomically correct positioning, and perhaps zooming, of images of celestial objects. Furthermore, such presentation metadata could be employed even beyond the scope of D2D, allowing users to exchange very simple show sequences between planetarium systems.

It is planned that D2D will be expanded in the future to also include 3D models, catalogue data (point clouds, including event data), spacecraft trajectories, streamed video (e.g. from a telescope) and more.

In the longer term, a glorious vision would be to be able to exchange show sequences between planetariums systems involving the full real-time functionality of the planetarium software, presenting exciting data in aesthetically pleasing ways. This would require a meta-scripting language that can be translated to the individual proprietary scripting languages of each vendor.

In summary: We invite all Planetarium Vendors to a) set up a cloud solution which synchronises the content metadata (in JSON format) as often as necessary, b) provide an interface that allows the presenter to search and filter the metadata instantaneously, c) download the presenter's chosen asset On Demand in any size needed, d) archive and rank the metadata, e) send the data assets to the render nodes (sliced if necessary), f) show them at the default location of the dome, and g) provide the planetarium presenter with a textual summary of the content on a console screen. We encourage all new *Content Providers* to get in contact with the D2D project, and to set up JSON files according to the specifications on the D2D web page.

References

- Abbott, B., Emmart, C. & Wyatt, R., Virtual Universe - Centuries of astronomy, plus video-game technology, offer a stunning new perspective on our place in space. AMNH Natural History magazine, April 2004.
- Alt, M. B. and Shaw, K. M. (1984). Characteristics of ideal museum exhibits. British Journal of Psychology, 75, pp. 25–36.
- Christensen, L.L, Moving the Pretty Pictures Into the 21st Century, Proceedings from Communicating Astronomy with the Public 2005, eds. I. Robson, & L.L. Christensen, 2005, pp.258–261
- European Commission, Eurobarometer 224/Wave 63.1: Europeans, Science and Technology (2005).
- Davies, R. & Christensen, L.L., Licensing of Astronomy Outreach Products 101, CAPjournal #20, 2016
- Falk (2007). Investigating public science interest and understanding: evidence for the importance of free-choice learning. Public Understanding of Science, vol. 16 (4), pp. 455–469.
- Hurt, R. , Christensen, L.L, Gauthier, A & Wyatt, R, Sharing Images Intelligently: The Astronomical Visualization Metadata Standard Proceedings from Communicating Astronomy with the Public 2007, eds. eds. L. L. Christensen, M. Zoulias & I. Robson, 2007, pp. 450–453
- Loch Ness Productions database, 2016, Accessed on 14.06.2016: https://www.lochnessproductions.com/reference/attendance/attendance.html
- Mori (2005). Science and Society. London: Office of Science and Technology.
- National Science Board (2014). Science and Engineering Indicators, Arlington: VA:NSF.
- Subbarao, 2016, Private Communication
- Tell, D.R. (2016), Planetarian, 45, 62
- Yu, K.C. (2009), Planetarian, 36, 6
- Yu, K.C., Sahami, K., Sahami, V., & Sessions, L.C., 2015, Using A Digital Planetarium For Teaching Seasons To Undergraduates, Journal of Astronomy & Earth Sciences Education, 2(1), 33–50,
- Yu, K.C., 2016, submitted

Box: Glossary

Asset: the type of content provided by the D2D system (metadata, images, videos etc.)
AVM: Astronomy Visualization Metadata Standard. A metadata standard that describes how metadata tags in the header of an image file can contain information such as position, orientation and size of the image on the sky, a popular description of the Content resource, credit information and more.
Client: The planetarium presentation or planetarium production system of a community member.
Cloud: A model for enabling ubiquitous, convenient, on-demand access to a shared pool of configurable computing resources like storage and computing.
Community: The ecosystem comprising all planetariums, companies and other institutions contributing to the planetarium world.
Content Provider: A (research) institution producing content, intended for dissemination through the D2D system.
Data: The high-res assets that will be presented on the dome: large images, video (incl. fulldome) and other data.
Data curator: A person or institution that ensures that the data available through the D2D system is up to date, scientifically accurate and aesthetically pleasing.
IPS: International Planetarium Society, Inc.
JSON feed: JavaScript Object Notation is an open-standard format that uses human-readable text to transmit data objects consisting of attribute–value pairs. It is a way to store information in an organised, human-readable, easy-to-access manner.
Metadata: Data (typical human readable text) that provides information about other data.
Meta-scripting language: A scripting computer language. It is possible to translate between different scripting language and the meta-scripting language back and forth in an unambiguous way.
Planetarium presenter: The person who lectures a planetarium show and interacts with the audience.
Planetarium software: A software rendering a simulation of the Universe as a function of time and the observer's location. Examples: Digistar, Dark Matter, Uniview.
Presenter menu: A window on the graphical user interface of a PC at the planetarium presenter's console. The interaction of the planetarium lecturer with the D2D system is done through this window. All content assets available in the D2D system are displayed in this window, subject to certain, user-defined filter rule such as object name or newness of an asset.
Script language: A structured computer language that allows to arrange media assets (videos, images, sound, 3D models, camera movements) to specify a planetarium show.
Sky Tonight live show: A typical planetarium show or show segment, often lectured live, presenting the starry sky as it can be seen from the planetarium's location at the day of the presentation.
Vendor: A company which sells or implements planetarium hardware, software, content and systems.

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Sandbox – not used

Does such a tool already exist?

Evans & Sutherland's Digistar5 and SkySkan's Dark Matter both have cloud solutions and considerable communities. However, neither of these are truly global solutions and the content contributors cannot be asked to provide data in several different formats. Also, these clouds are not necessary curated or ranked in a way that migrates the best content to the top of the rankings. However, such data clouds could possibly be integrated in this system, and we can learn from the existing cloud solutions.

Implementation Strategy

In order to keep the associated workload limited, one strategy for the implementation of the D2D system could be to concentrate on the vendor-independent scripting for the moment. This is an effort that has to be driven by the community (rather than by the vendors).

For the data distribution it could make sense to just wait until more vendors follow E&S and implement their own real cloud solutions.

Scripting language

The vendors' planetarium systems have different philosophies on how data is handled. This can be illustrated by the task of loading and displaying an image on the dome:

- Digistar always works in a 3D scene (true for versions 3-5):
    1. Load a polygonal model (i.e. a flat surface)
    2. Load a texture resource and map it onto the model
    3. Explicitly add the model to the scene
    4. Position and rotate the model
- Digital Sky 2.x is in a 2D "mode" for images but can also do it 3D, but then you need to deal with the fact that the camera is at your location and not at (0, 0, 0) which can be a bother.
    1. Load a texture resource and already give it a coordinate system (i.e. astronomical vs. dome) and other properties
    2. Position and rotate the object on the dome coordinate system
    3. Fade it up and set the color (all in one command, not separable)
- Sky Explorer: There are only 3 commands:
    1. additem (loads a 3d model)

2. modifyitem (always give ALL ~180 parameters)
3. deleteitem

Not sure how they would load a single image.

- Uniview is now able to load single images at run-time. No idea if that is scriptable.
- Powerdome: Image class object are loaded in the timeline. The timeline is an XML file, as is the show description file.

Appendix 1: Simple Implementation in a Kiosk-mode

To gather some momentum a simple implementation of existing data sources will be made and presented on an html5 kiosk.

This kiosk application will become a significant portion of the ESO Supernova Preshow.

And can then mostly likely also be shown directly to the presenter in several planetarium systems (although the dome integration of course will take more work).

Maybe a “menu” where data sources can be selected and un-selected would be good.

The blue examples below can already today be added to ESO’s ESOnews html5 Kiosk.

Data sources:

- The Sun right now: http://sohowww.nascom.nasa.gov/data/realtime/mdi_igr/1024/latest.jpg
  SOHO [timestamp]
- The VLT right now: http://www.eso.org/public/archives/static/pano/latest/pano_PV.jpg
  SOHO [timestamp]
- ALMA right now: (coming)
- Astro-news: (three latest Featured News from PTTU)
- The ESO Supernova right now:
  http://supernova.eso.org/static/web/frontpage/webcam/last_hqe2.jpg
  ESO Supernova right now [timestamp]

Appendix 2: Manpower and Motivation

The ESO Supernova

To address these issues, the ESO Supernova has pledged to develop such a real-time, data-driven distribution system for the planetariums in Germany, the ESO Member States and the rest of the world. The aim is to significantly shorten the delay between the availability of a news item — which might be an image, a 3D model, or even a whole dataset — and the presentation of this item in planetariums. The result will be a daily Sky at Night live planetarium presentation as up to date as the daily weather forecast on TV. Timescale: Ready for August 2017.

Resources

Up to 1 FTE over 2016-2017. A bit of travel money.
3-10 volunteers.

OpenSpace

Carter Emmart from AMNH is working with Anders Ynnerman from Linköping University on developing a new data-driven planetarium software called *OpenSpace.* The work is supported by NASA, Linköping University and others. There may be some obvious advantages of tying the philosophies and methodologies of D2D together with *OpenSpace.*

Resources

Recently funded by NASA (3-5 M$). Possibly significantly involvement from Singapore University.

Münster Planetarium

Needs to update a show about the planets weekly or monthly with the latest press releases and images about planets. Timescale: Ready for 1.03.2017.

Resources

A fraction of an FTE to develop code.

Large Synoptic Survey Telescope / Adler Planetarium

The Large Synoptic Survey Telescope's (LSST) outreach program involves delivering content and datasets to the planetarium community. A standardized D2D system will significantly simplify that task.

Resources:

Starting 2017 there will be 1 FTE at the Adler Planetarium working on museum and planetarium LSST outreach. A significant fraction of this person's time ⅓ - ½ could be spent on D2D development. Professional development workshops may also be held.

Server-Side Data Formats

For the vendor-neutral scripting language, it is suggested to define a scripting meta-language based on e.g. XML. Script content created in system A would be translated first to the meta-language and then to the script languages of all other targeted planetarium systems B, C, etc. In addition to the script itself, also meta information about the show or show segment has to be stored — e.g. the name of the segment, its length and who to credit. This could be implemented in the XML tags as well.

List of Vendors/Softwares to involve

1. Digistar/E&S
2. Dark Matter/Sky-Skan
3. Uniview/Sciss
4. Powerdome/Zeiss
5. SkyExplorer/RSA Cosmos
6. Mitaka/NAOJ
7. OpenSpace
8. World Wide Telescope/AAS
9. ShiraUniverse/SureyyaSoft

It is an open question whether all data of the D2D system shall be saved in a Repository on one central server (or distributed server architecture) or rather the system is kept decentralized as an Aggregation service like iTunes (pointing to the data residing with each content contributor). With decentralization, however, comes the need to operate one single aggregation service pointing to all available show assets. The Digistar cloud, already in operation, is a Repository using Amazon's IT resources.

Another option would be to just rely on the vendors' cloud solutions. Why reinvent the wheel? The vendor-neutral scripting language, may be more important than the cloud, to interoperate.

The main functionality of fulldome systems includes storing all real time data on each hard drive of each render node locally due to efficiency reasons. This means: all data that has been downloaded from the cloud must be distributed to all nodes.
[vocabulary: Zeiss: nodes, Sky-Skan: renderers, E&S: graphics processors (GPs)]
The cloud downloads must go to a specific folder. Proposal:

- E&S Digistar 5: $Content\User\ D2D\...
- Sky-Skan DS 2.3, 2.4: ShowPath\ D2D\... for realtime data, SndPath\ D2D\... for Audio, SvPath\ D2D\... for full dome video etc.
- Sky-Skan Dark Matter: - please specify -
- Zeiss Powerdome: -please specify-
- RSA Sky Explorer: -please specify-
- Sciss Uniview: -please specify-
- Shira Universe : MainPath\Data2Dome\..

The cloud “downloader” should be aware of what already has been downloaded (i.e. if you modified the content and it needs to be re-downloaded) and should clean up the system on request.

Further examples for location-based events are solar eclipses and occultations. These are events worth mentioning in a planetarium show if they apply to the audience.
Implementation: Contact has been established with Heavens-Above GmbH, the company behind the website of this name. The concept developed in a meeting with their director, Chris Peat, calls for an API running on HA’s servers. The location and the Julian Date in question are transmitted to their server, and e.g. the path of the satellite along the sky and the magnitude development are returned. It was agreed that HA shall get visibility in return, such as logo placement.

Content of particular interest includes:, also solar eclipses.

Disruption of Observations at Mauna Kea

1. An event takes place or or near Mauna Kea, Hawai’i, like a volcano eruption or a public demonstration blocking access to the telescopes.
2. A trusted content contributor publishes a visualisation in the KML format visualizing the location of the event on top of the Earth model.
3. Thus asset is ranked high because it is an up-to-date event.
4. Users can download it with the simple click of a button and display it on the dome.

Best image of Ganymede

1. The presenter quickly needs the best image available of Ganymede (or any other named object in space).
2. A trusted content contributor has prior identified, and uploaded one of the best images of Ganymede (with metadata).
3. The system allows for a split-second search and selection of the best image (size, quality, and content contributor's standing are shown clearly).
4. Asset is displayed on dome. The author has already specified that the image shall appear centered on 45 deg elevation in the South, with a size of 30 deg x 30 deg. However, the planetarium operator has also the freedom to change this default to whatever suits best for the particular show.

Real-time lectures (tours)

Flexibility in how the talk is presented; the presenter can spend more or less time at each star, constellation, deviate from the original plan according to audience's interests, and take questions and requests on the spot. It may be the best way for a large audience to intuitively experience a digital universe, listen to a lecture or participate in a discussion. The limited research that has looked at the impact of immersive digital visualizations on audiences has shown long-term engagement and interest in science topics. For example, 300 written evaluations and 46 interviews with visitors at the 'Gates Planetarium' at the Denver Museum of Nature & Science (DMNS) live lectures with full dome real-time visualisations showed a significant increase in visitors' interest in the topics presented after the lecture compared to their interest before (Yu, 2009): 43% tried to learn more after the lecture. FORMAT: 60mins lecture, twice per month (e.g. Digital Earth since 2008)

Weather tonight in my location

1. Eumetsat continuously receives satellite imagery of the Earth and offers it for usage through EumetCast.
2. A content contributor has made an "app" that uses this data to provide regularly updated cloud maps of the Earth through the D2D cloud.
3. A lecturer thinks this is great, downloads the up-to-date cloud map and uses it. The cloud map is automatically wrapped around the Earth model for this purpose.

Space Weather Live

1. A giant flare is erupting on the Sun.

2. A content contributor has made an App that allows the simultaneous display of data from Stereo A and B of the solar surface, as well as real-time measurements of the Earth's magnetosphere.
3. The presenter shows all three data sources and explains how the particle emission will hit the magnetosphere in three hours.

Earthquake near an observatory

1. A significant earthquake (M > 6) takes place near one of the observatories in the North of Chile.
2. A content contributor publishes a visualisation in the KML format visualizing the seismic waves on top of the Earth model.
3. This asset is ranked high because it is an up-to-date event.
4. Users can download it with the simple click of a button and display it on the dome.

Programmatic content such as timelines and scripts: most (if not all) real-time planetarium systems come either with a timeline editor or with a script language to arrange content assets to a real-time-rendered show. In the case of timelines, the underlying implementation is yet again a script. A simple, generic, vendor-neutral scripting language that can be translated to the vendors' proprietary script languages might be necessary to ensure that the D2D system bridges vendor boundaries.

Json feed example of a fulldome video:


```
[{
        lang: "en",
        credit: "<p>ESO...,
        width: 4096,
        height: 4096,
        description: "<p> Video description...",
        title: "The planetarium show "From Earth to the Universe"",
        headline: "",
        formats_url:
        {
    potwmedium: "https://www.eso.org/public/archives/videos/potwmedium/eso-fettu.jpg",
    dome_preview:
    "https://media.eso.org/public/archives/videos/dome_preview/eso-fettu.mp4",
    thumb: "https://www.eso.org/public/archives/videos/thumb/eso-fettu.jpg",
```

dome_2kmaster:
"https://media.eso.org/public/archives/videos/dome_2kmaster/eso-fettu.zip",
dome_4kmaster:
"https://media.eso.org/public/archives/videos/dome_4kmaster/eso-fettu.zip",
videoframe: "https://media.eso.org/public/archives/videos/videoframe/eso-fettu.jpg",
thumb350x: "https://www.eso.org/public/archives/videos/thumb350x/eso-fettu.jpg",
newsmini: "https://www.eso.org/public/archives/videos/newsmini/eso-fettu.jpg",
thumb300y: "https://www.eso.org/public/archives/videos/thumb300y/eso-fettu.jpg",
newsfeature: "https://www.eso.org/public/archives/videos/newsfeature/eso-fettu.jpg",
news: "https://www.eso.org/public/archives/videos/news/eso-fettu.jpg",
dome_mov: "https://media.eso.org/public/archives/videos/dome_mov/eso-fettu.mov",
original: "https://www.eso.org/public/archives/videos/original/eso-fettu.tif"
},
release_date: "2015-06-09T14:00:00",
id: "eso-fettu"
}]

JSON feed example of an image including AVM metadata:

[{
Spectral.CentralWavelength:
[
"550",
"660",
"658"
],
ResourceURL: "http://www.eso.org/public/archives/images/original/eso1238a.tif",
Title: "Thor's Helmet Nebula imaged on the occasion of ESO's 50th Anniversary",
Headline: "",
ResourceID: "eso1238a",
Contact.PostalCode: "D-85748",
Instrument:
[
"FORS2",
"FORS2",
"FORS2"
],
Spatial.CoordsystemProjection: "TAN",
Spatial.ReferenceDimension:
[
"3424.0",
"3437.0"
],

Spatial.ReferencePixel:
[
"1696.96799913",
"1661.6804125"
],
Type: "Observation",
Subject.Category:
[
"B.3.2.4",
"B.4.1.2"
],
Spectral.Bandpass:
[
"B",
"V",
"R"
],
Publisher: "European Southern Observatory",
Description: "This VLT image of the Thor’s Helmet Nebula was taken on the occasion of ESO’s 50th Anniversary, 5 October 2012, with the help of Brigitte Bailleul — winner of the Tweet Your Way to the VLT! competition. The observations were broadcast live over the internet from the Paranal Observatory in Chile. This object, also known as NGC 2359, lies in the constellation of Canis Major (The Great Dog). The helmet-shaped nebula is around 15 000 light-years away from Earth and is over 30 light-years across. The helmet is a cosmic bubble, blown as the wind from the bright, massive star near the bubble's centre sweeps through the surrounding molecular cloud.",
Temporal.IntegrationTime:
[
"",
"",
""
],
Distance.Notes: "",
Spatial.Notes: "",
Spectral.ColorAssignment:
[
"Blue",
"Green",
"Red"
],
Spatial.Equinox: "J2000",
MetadataDate: "2015-01-14T03:46:30",

PublisherID: "eso",
Distance:
[
"15000.0",
null
],
Spatial.Quality: "Full",
Spatial.CoordinateFrame: "ICRS",
Temporal.StartTime:
[
null,
null,
null
],
Rights: "Creative Commons Attribution 4.0 International License",
formats_url:
{
potwmedium: "https://www.eso.org/public/archives/images/potwmedium/eso1238a.jpg",
thumbs: "https://www.eso.org/public/archives/images/thumbs/eso1238a.jpg",
thumb150y: "https://www.eso.org/public/archives/images/thumb150y/eso1238a.jpg",
thumb700x: "https://www.eso.org/public/archives/images/thumb700x/eso1238a.jpg",
banner1920: "https://www.eso.org/public/archives/images/banner1920/eso1238a.jpg",
medium: "https://www.eso.org/public/archives/images/medium/eso1238a.jpg",
screen: "https://www.eso.org/public/archives/images/screen/eso1238a.jpg",
thumb350x: "https://www.eso.org/public/archives/images/thumb350x/eso1238a.jpg",
newsmini: "https://www.eso.org/public/archives/images/newsmini/eso1238a.jpg",
zoomable: "https://www.eso.org/public/archives/images/zoomable/eso1238a",
news: "https://www.eso.org/public/archives/images/news/eso1238a.jpg",
wallpaperthumbs:
"https://www.eso.org/public/archives/images/wallpaperthumbs/eso1238a.jpg",
original: "https://www.eso.org/public/archives/images/original/eso1238a.tif",
large: "https://www.eso.org/public/archives/images/large/eso1238a.jpg",
thumb300y: "https://www.eso.org/public/archives/images/thumb300y/eso1238a.jpg",
newsfeature: "https://www.eso.org/public/archives/images/newsfeature/eso1238a.jpg",
wallpaper4: "https://www.eso.org/public/archives/images/wallpaper4/eso1238a.jpg",
wallpaper5: "https://www.eso.org/public/archives/images/wallpaper5/eso1238a.jpg",
screen640: "https://www.eso.org/public/archives/images/screen640/eso1238a.jpg",
wallpaper1: "https://www.eso.org/public/archives/images/wallpaper1/eso1238a.jpg",
wallpaper2: "https://www.eso.org/public/archives/images/wallpaper2/eso1238a.jpg",
wallpaper3: "https://www.eso.org/public/archives/images/wallpaper3/eso1238a.jpg"
},
Spatial.Scale:

[
"-3.509242e-05",
"3.509242e-05"
],
ReferenceURL: "http://www.eso.org/public/images/eso1238a/",
Credit: "ESO/B. Bailleul",
MetadataVersion: "1.1",
Spectral.Notes: "",
Contact.Address: "Karl-Schwarzschild-Strasse 2",
Spatial.Rotation: "90.13006012532",
ID: "eso1238a",
DatasetID:
[
"",
"",
""
],
Contact.StateProvince: "",
CreatorURL: "http://www.eso.org/",
Facility:
[
"Very Large Telescope",
"Very Large Telescope",
"Very Large Telescope"
],
Spatial.ReferenceValue:
[
"109.625371",
"-13.23017"
],
Creator: "European Southern Observatory",
Spectral.Band:
[
"Optical",
"Optical",
"Optical"
],
Date: "2012-10-05T16:00:00",
Contact.Country: "Germany",
Contact.City: "Garching bei München",
Subject.Name:
[

```
            "NGC 2359"
            ]
}]
```

Data and metadata from *Content Providers* will be “harvested” via “scraping” or produced and stored in the *D2D* database. The best content will be featured in a human curation process and offered to the Presenters on the client side. Here the D2D system will seamlessly integrate into the GUI of the planetarium system. Filter and search functionalities will ensure that the intended content topic and type can be found within a short moment of time. Once a certain content component is selected, it is downloaded and *the Vendor* will arrange that the data assets are automatically sent to the render nodes, sliced if necessary, and installed at the appropriate location for easy display (at the default location of the dome, i.e., the “sweet spot”, with the default size if not specified otherwise). Furthermore, the planetarium presenter is offered a textual summary of the content on a console screen.

The presenter’s access to the D2D assets could be given in three different ways.

1. **A centralised universal repository** could be gathered with all metadata and highres assets from all content providers. This could be searched from within the planetarium software and the highres assets downloaded.
   We do not see this model as practically realistic to implement as no one would be able to provide the resources to keep this fully updated.
2. **Directly from the content providers to the planetarium software**: The *D2D project* (and each data provider) could provide the metadata and highres assets directly to each planetarium. for instance from within the planetarium system’s GUI in an html5-compatible browser. The browser could generate a JSON configuration file with metadata and links to the high-resolution assets to be imported in the *Vendor’s planetarium system*. Each planetarium software would need to be able to read this file, download the high-res assets, and present them on the dome and show the metadata to the presenter. This would be a fairly easy way to keep D2D low maintenance (as it is independent of the vendors).
   A simple proof-of-concept is here, allowing the Presenter to pick a number of images and receiving a json feed with information (kept minimal in this case) and a deep link to some highres assets:
   https://supernova.eso.org/d2d/dash/
3. A faster way to get an implementation up and running would be for the **D2D system to continuously synchronize all metadata (and highres?) assets to each vendor’s cloud**. This would make it easier for the vendors to offer the assets to the presenter in the way they find suitable, but a bit harder for the D2D system to provide all vendors with the assets (both in terms of initial set-up and maintenance of the system). Currently not all planetarium software systems are able to accept these data, but most should be ready to do so in the near future.

The metadata could be delivered in the form of a json feed with limited size, similar to this example (for HST): http://www.spacetelescope.org/images/json/

The offered D2D data would be presented in a menu curated partly by human curators and partly by algorithms. The will likely be quite a large range of products from a number of content contributors so it is critical that the system features a rating system to make content with the best quality the most accessible/visible.

With the number of content contributors rising, a quality assessment/indication will be introduced, such as a combination of downloads and "Thumbs-Up" or "+1" voting scheme. Since the number of downloads and quality of assets improves with time, the total ranking needs to also factor in the time since the asset was published.

The content shall be tagged with a date, so that data clearly become less relevant with time (e.g. the cloud maps of one year ago) and do not make the hard drives overflow. A "best before" date and a clean-up mechanism is mandatory. If a user wants to keep media used in a presentation, he/she can copy it to another place and it won't be cleaned up — or simply change the best before date.

Open Issues

Some of the pitfalls in a project like this are:

1. **Curation and ranking**: Cloud solutions tend to get polluted by inferior data. Well-working ranking schemes are really difficult to make (that's how Google made billions).
2. **Raw data vs. polished "presentable" PR data**: A related issue is the way that laypeople "see" crude, noisy, raw data vs. polished "presentable" PR data issue also found elsewhere in outreach.
3. **How to get vendors on board**: For vendors whose systems already have cloud functionality (e.g. E&S), the D2D content can be disseminated through this cloud in implementation model 2 above, in this way addressing a large audience (without the need to advertise any separate cloud). Other vendors will need to implement a cloud to continuously receive the D2D data, or implement another solution - e.g. a plugin interpreting the json feed.
4. **Legal issues**: The Content providers must guarantee that everything in the cloud is free to use for the planetariums (preferably under a Creative Commons Attribution license, see Davies & Christensen, 2016).

Man-made satellites over my position

Shows the visibility of man-made satellites such as Iridium Flares, ISS, Hubble (where visible), over the location of the observer on the surface of the Earth.

The last 7 days' press releases about the Solar System

1. For a planetarium show about planets, a 10-minute segment at the end is reserved for "recent Solar System discoveries"
2. The PTTU module of D2D has metadata tags for press releases in different areas, including "Solar System".
3. The presenter selects the D2D News menu overview and the metadata tag "Solar System".
4. The presenter picks the most interesting/relevant releases, downloads the data/high-res assets and presents them to the audience

Number of events: Around 10
Increment per year: 100
Implementation: This use case will also be implemented by the PTTU module of D2D.