TOTAL APPEARANCE CAPTURE

ESSENTIAL TOOLS FOR APPEARANCE CENTRIC SUPPLY CHAIN VIRTUALIZATION

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APPEARANCE

≠ JUST COLOR!

≠ JUST A PICTURE!

= THE **VISUAL SENSATION** THROUGH WHICH AN OBJECT IS PERCEIVED TO HAVE ATTRIBUTES AS **SIZE**, **COLOR**, **TEXTURE**, **GLOSS**, **TRANSPARENCY**, **OPACITY**, ETC.!

ALL THESE OBJECTS ARE BLACK BUT THE APPEARANCE VARIES SIGNIFICANTLY

TOTAL APPEARANCE CAPTURE IS THE DIGITIZATION OF MATERIALS WITH TRUE, FULL **APPEARANCE** MEASUREMENT.

Perceptual Transformations
- Contrast Sensitivity
- Tone-mapping
- Adaption
- Context

Scene
- Direct/indirect lighting
- Lighting color
- Surround
- Object proximity

Material
- Composition
- Physical Properties
- Optical Properties

Viewer
- Distance
- Angle

Geometry
- Size
- Shape
- Surface Texture
- Construction

APPEARANCE

APPEARANCE CONSISTS OF:
- **COLOR**
- **TEXTURE (SPATIAL VARIATION IN COLOR)**
- **GLOSS**
- **VARIATION OF HEIGHTS**
- **TRANSLUCENCY OR TRANSPARENCY**

- is the vehicle to describe and transport appearance
- is “neutral”, platform- and device-independent
- makes appearance exchangeable and tradable
- functions as a “tamper-proof” material standard
- allows material certification
- connects to real-world materials and SKUs
- drives the PANTONE Material Nomenclature (PMN)

INTRODUCTION: **ENABLING REALISM**

Creation

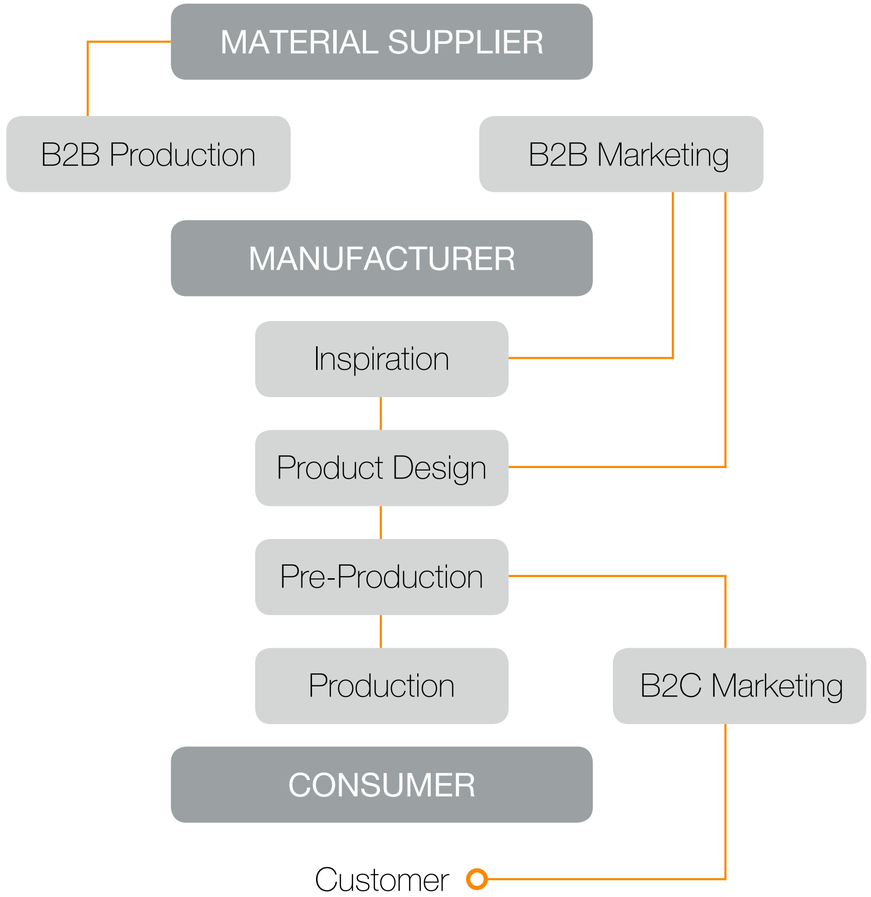
- Cost savings replacing physical samples Simplified maintenance of material libraries Simplified logistics for digital samples Instant availability through digital deployment Flexibility to explore different materials Creation of customized materials
- Re-use of existing materials to design derivatives and variants

Production

- Cost saving & accelerated design by less physical prototypes
  Improved communication by more accurate renderings Design comparison & consistency by measured appearance
- Simplified logistics & shortened ‘digital’ turn-around Systematic appearance-based quality control

Marketing

- More accurate rendered marketing materials
  Cost savings through re-use of digital design materials Accurate renderings improve customer communication e-commerce & showroom improved by true realism



TOTAL APPEARANCE CAPTURE VALUE PROPOSITIONS AND HIGH LEVEL PROBLEMS ADDRESSED

1
- COST SAVINGS THROUGH REPLACEMENT OF PHYSICAL SAMPLES
- SIMPLIFIED MAINTENANCE OF MATERIAL LIBRARIES
- SIMPLIFIED LOGISTICS FOR DIGITAL SAMPLES
- INSTANT LIBRARY AVAILABILITY THROUGH DIGITAL DEPLOYMENT

2
- HIGHER CREATIVE FLEXIBILITY TO EXPLORE DIFFERENT MATERIALS
- CREATION OF MANUFACTUREABLE CUSTOMIZED MATERIALS

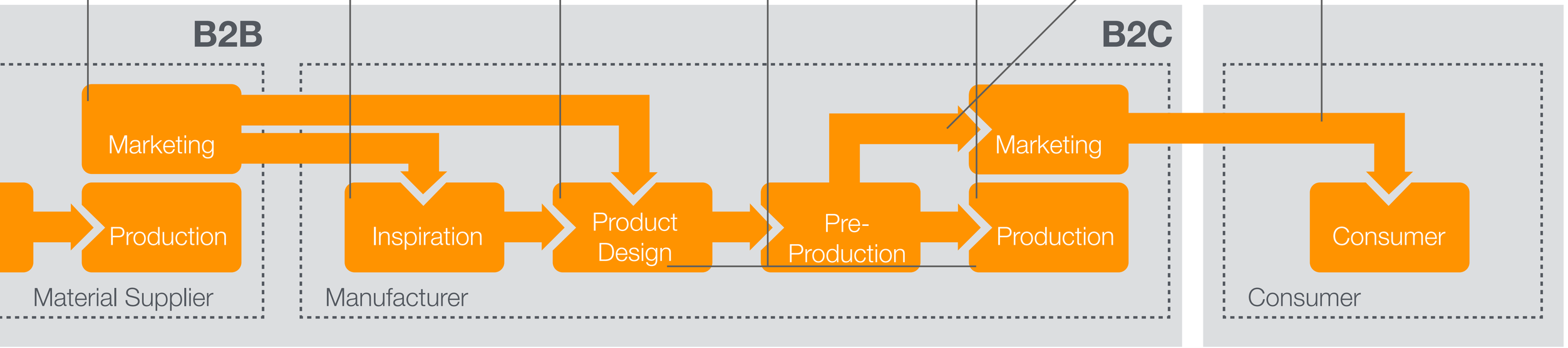
3
- COST SAVINGS AND ACCELERATED DESIGN PROCESS THROUGH REDUCTION OF PHYSICAL PROTOTYPES
- IMPROVED COMMUNICATION WITH STAKE HOLDERS THROUGH MORE ACCURATE RENDERINGS

4
- COMPARE DESIGN SPECIFIED APPEARANCE WITH REAL-LIFE (MEASURED) APPEARANCE ON PRODUCTION LINE TO IMPROVE CONSISTENCY
- SIMPLIFIED LOGISTICS AND SHORTEND TURN-AROUND CYCLES THROUGH DIGITALIZATION

5
- APPEARANCE-BASED QUALITY CONTROL ON PRODUCTION LINE (STATISTICAL OR SYSTEMATICAL)

6
- MORE ACCURATE RENDERINGS FOR MARKETING MATERIALS AND COST SAVINGS THROUGH RE-USE OF DIGITAL MATERIALS FROM DESIGN PROCESS

7
- IMPROVEMENT OF COMMUNICATION WITH CUSTOMER THROUGH MORE ACCURATE PRODUCT RENDERINGS (ESPECIALLY FOR BUILD-TO-ORDER PRODUCTS)
- ENEABLING/IMPROVEMENT OF E-COMMERCE AND SHOWROOM / BRICK-AND-MORTAR EXPERIENCE WITH REALISTIC MATERIAL CONFIGURATORS / LIBRARIES



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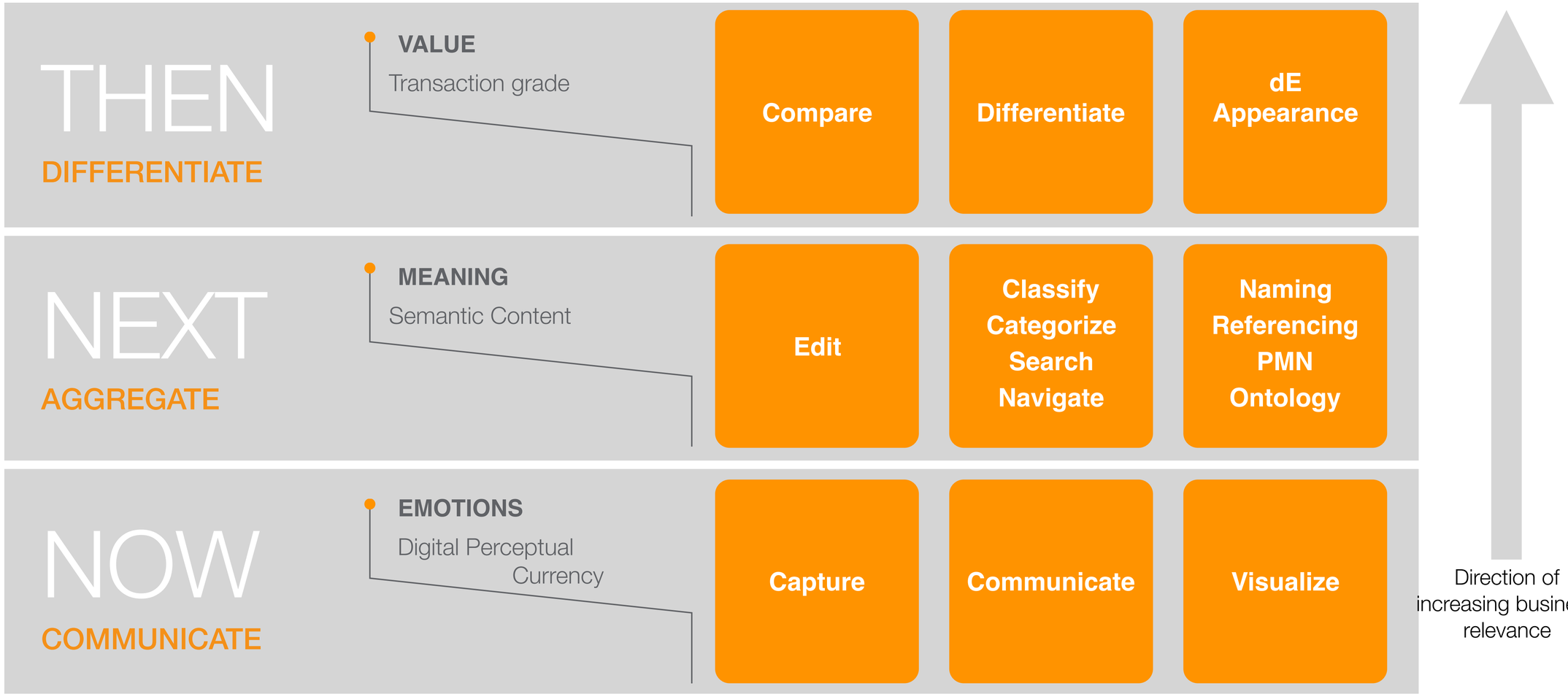
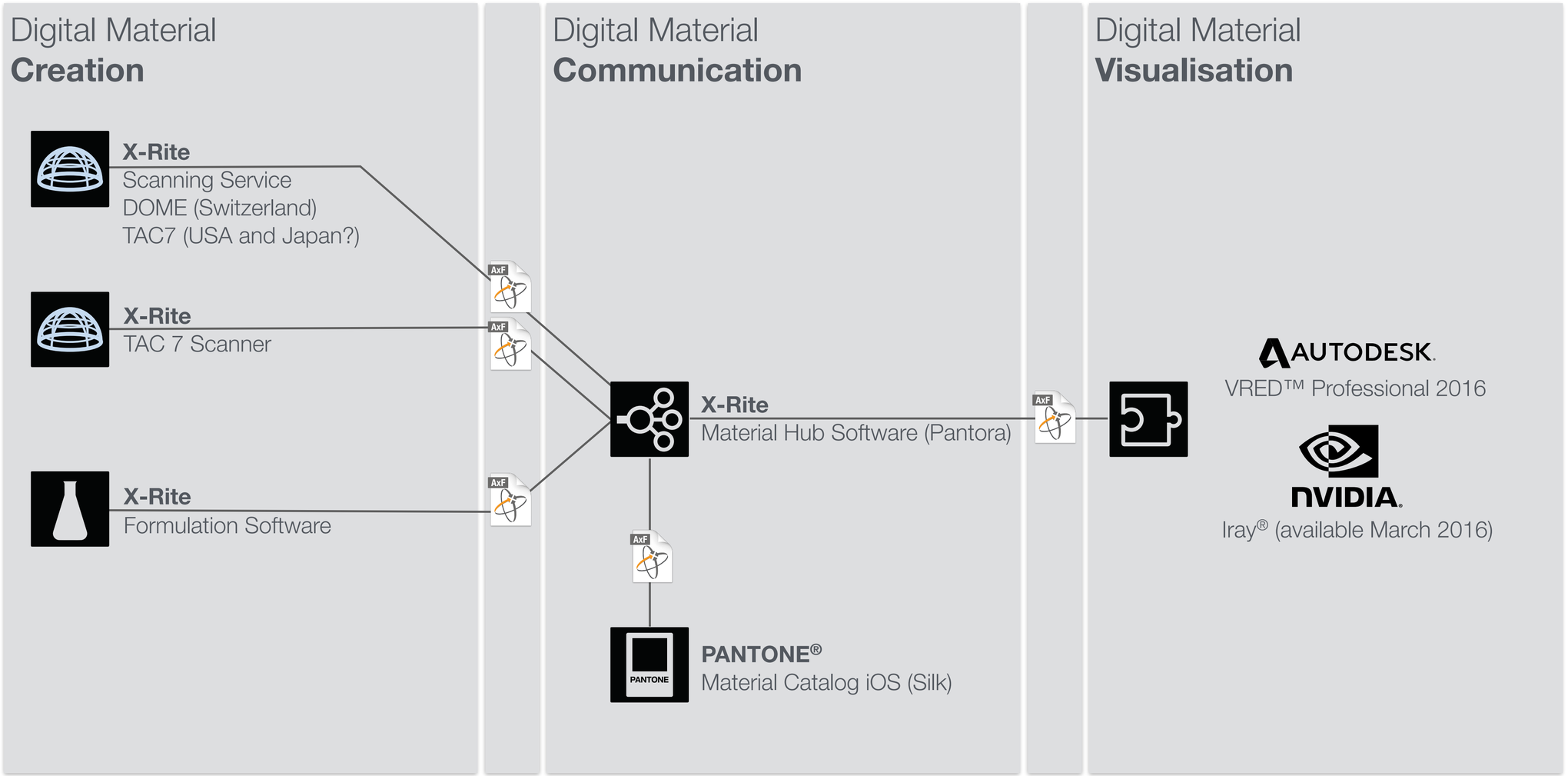
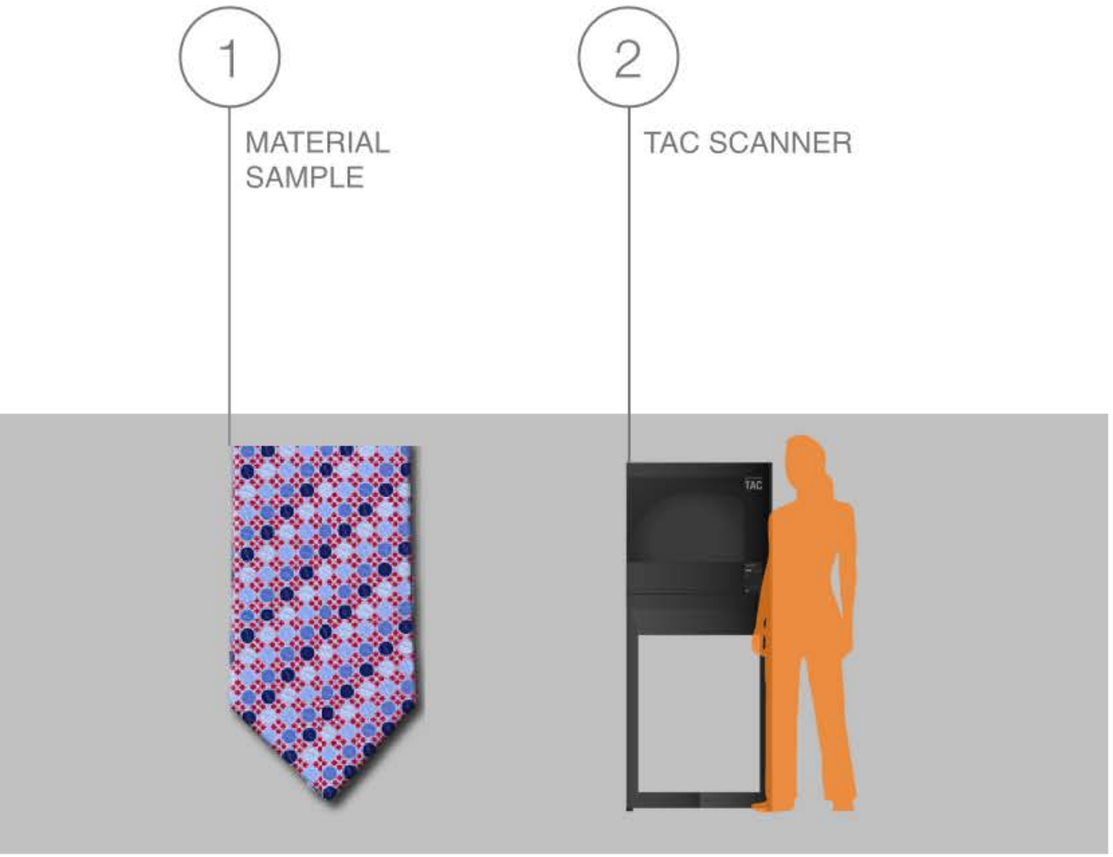
THE ECOSYSTEM OF DIGITAL APPEARANCE: **FUNCTIONAL ARTICULATION**

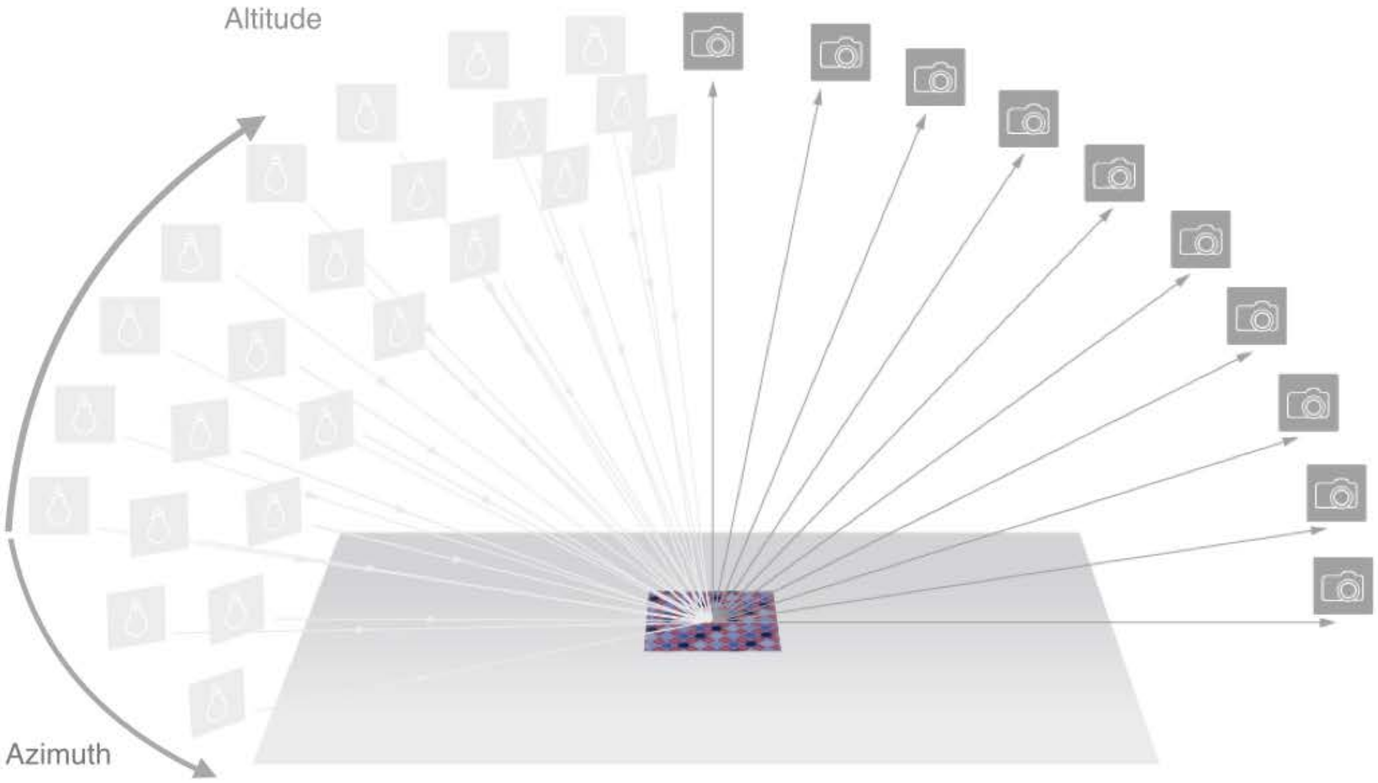


X-RITE TOTAL APPEARANCE CAPTURE ECO SYSTEM



INTRODUCTION: **HOW IS A MATERIAL VIRTUALISED?**





INTRODUCTION: **HOW IS A MATERIAL VIRTUALISED?**

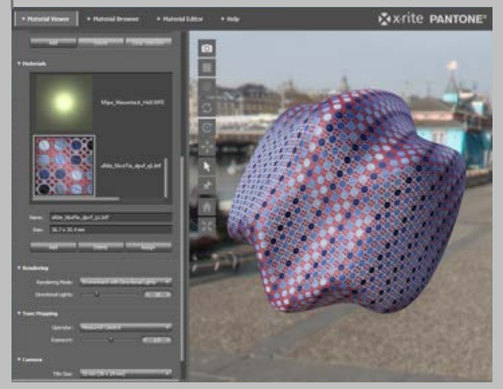
3

POST-PROCESSING GENERATES AN APPEARANCE EXCHANGE FORMAT (AxF) FILE

4

THE PANTORA MATERIAL HUB OFFERS:

- TAC7 DEVICE CONTROL
- POSTPROCESSING
- MATERIAL EDITING
- VENDOR NEUTRAL MATERIAL LIBRARY MANAGEMENT



5

THE VIRTUAL LIGHT BOOTH ENABLES QUALITY ASSESSMENT BETWEEN THE REAL AND THE VIRTUAL MATERIAL

6

RENDERING APPLICATIONS LIKE AUTODESK VRED OR NVIDIA IRAY CAN ALREADY READ THE AXF FORMAT. PANTORA ALSO OFFERS EXPORT TO SOME OTHER MATERIAL FORMATS.

TOTAL APPEARANCE CAPTURE RENDERING PROCESS

1

- Radiometrically calibrated images from TAC7 device

2

- AxF SVBRDF
  - normal-map
  - spatially varying parameters for analytical BRDF model
  - different BRDF models for different types of material samples
  - diffuse albedo is obtained as calibrated trichromatic or multi-spectral
  - height map

3

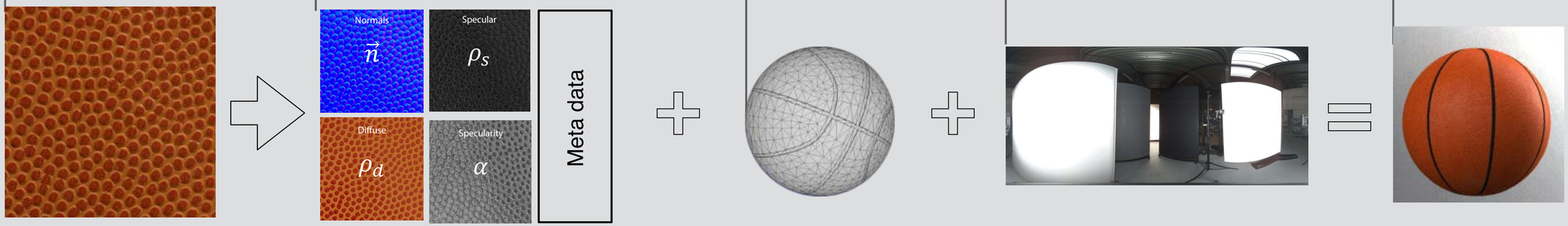
- CAD wireframe model of object

4

- 360° High-dynamic-range image of environment

5

- Photorealistic rendering



unbiased, spectral rendering pipeline

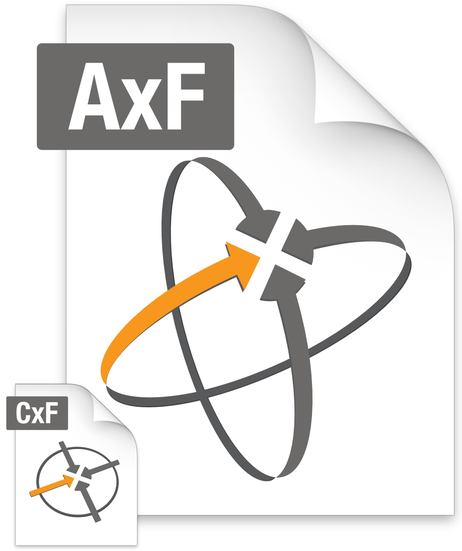
CxF VS. AxF - X-RITE EXCHANGE FORMATS

The data format to communicate color digitally is the

Color eXchange Format (CxF)

CxF was originally developed by X-Rite in the early 2000s as a universal language for transporting **complete color information** from concept to final production across devices, applications and geographies. It was handed over to the International Standards Organisation and has now been published as an ISO standard: **ISO17972 Graphic technology – Colour data exchange format (CxF/X)**

CxF is based on **XML** and can include spectral color values, named colors such as PANTONE®, color spaces and appearance effects (specific lighting conditions, type of substrate, type of ink, density, opacity, transparency of the color, gloss, texture, position and shape of color patches), as well as commercial aspects, mathematical, optical conditions, etc.



- COLOR
  - TEXTURE (SPATIAL VARIATION IN COLOR)
  - GLOSS
  - VARIATION OF HEIGHTS
  - TRANSLUCENCY OR TRANSPARENCY

The data format to communicate appearance digitally is the

Appearance eXchange Format (AxF)

AxF is a newly developed data container to transport **complete appearance information** of materials across devices, applications and geographies.

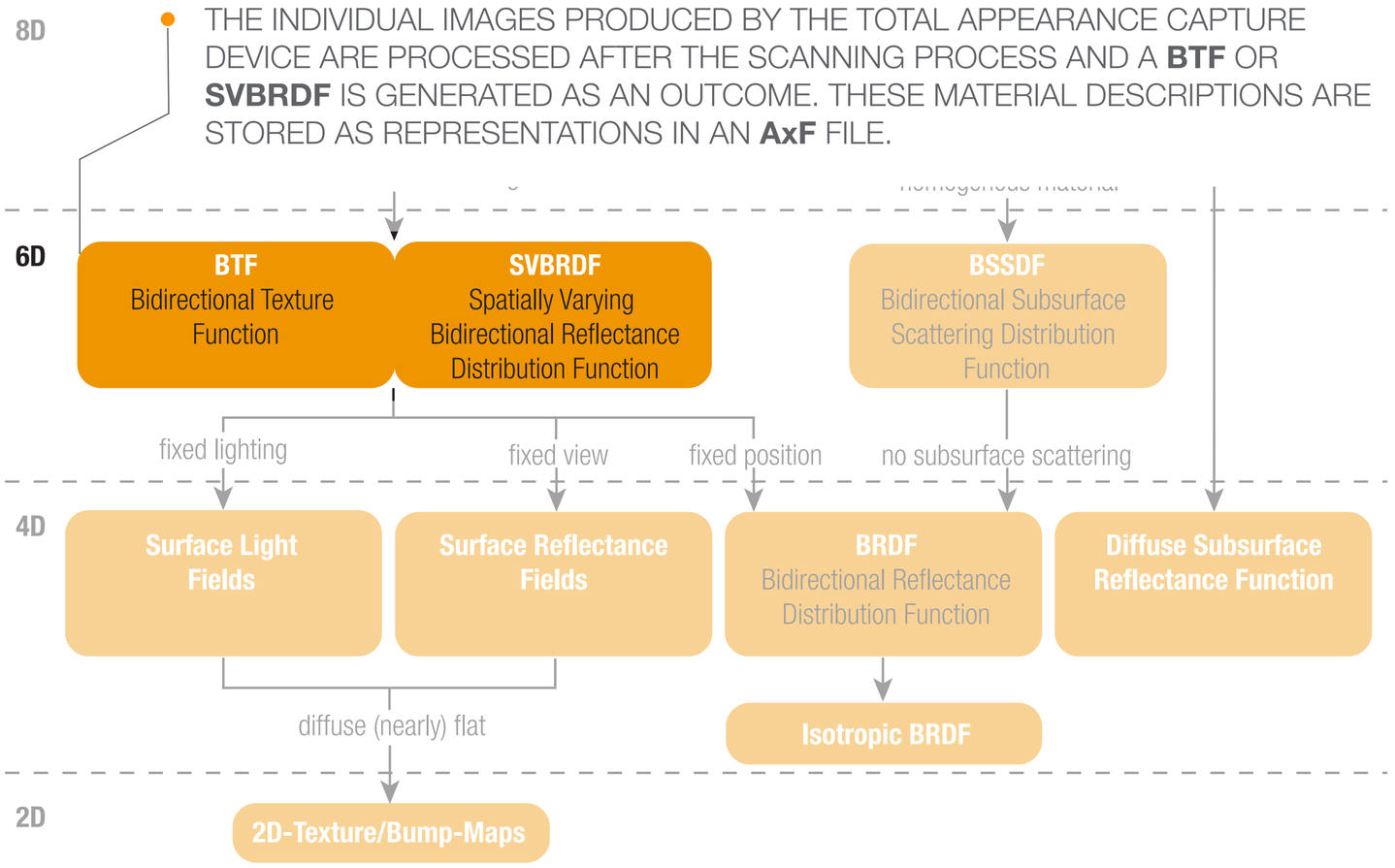
In contrast to CxF the information is stored as **binary data** to master the significantly bigger data volume which is needed to describe the total appearance of a material.

AxF is developed as an **complement to the CxF** format and it is able to store CxF based color information inside to save the color information of an material.

It is our intend that the format gets the same wide adoption across different application and devices like the CxF format today.

MODELLING LIGHT TRANSPORT: HIERARCHY OF B*x*DF FUNCTIONS

- Reflectance functions (**B*x*DF**) are a set of multidimensional mathematical functions which describe the way in which light interacts with the surface of a material.
- **B*x*DF**s are often used in computer graphics for photorealistic rendering of synthetic scenes and in the field of computer vision for object recognition.
- The original idea was to abstract light transport from geometric and physical detail
- The different reflectance functions vary in complexity and are typically limited to specific material types (e.g. transparent or opaque materials).



BTF, FITTING AND SVBRDF | AN ANALOGY FROM 2D COMPUTER GRAPHICS

BITMAP GRAPHICS = BTF

BITMAP to VECTOR CONVERSION = FITTING

VECTOR GRAPHICS = SVBRDF

BTF (chunked data)

+ works for most material types regardless complexity
– requires **FULL BTF** acquisition (long measurement time, complex instruments, lots of data)
– AxF: big file size
– limited editing capabilities

SVBRDF

+ works with **SPARSE BTF** data (shorter measurement time, simpler instruments, less data)
+ AxF: smaller file size and scalable compression
+ good editing capabilities
– results of fitting process dependent on complexity of material

WORKFLOW DIFFERENCES DOME AND TAC7

1

- Data acquisition

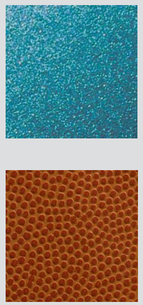
2

- Post-processing

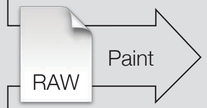
3

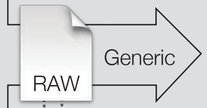
- Data format / material representations

DOME



- **FULL BTF** (raw data)
  - up to **1.5 TB** data
  - up to **8 hours**

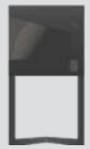


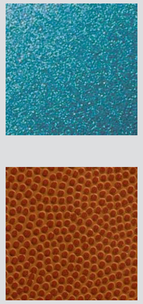


- Full BTF **fitted to Carpaint** model (BRDF + BTF)
  - 100 MB data typical
  - up to 30 minutes
- **Full BTF** (compressed)
  - up to 250 MB data
  - up to 10 hours

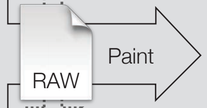
- CPA (car paint)
- Chunked Data (BTF)

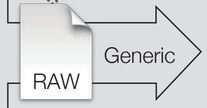
TAC7





- **SPARSE BTF** (raw data)
  - up to **20 GB** data
  - up to **30 minutes**

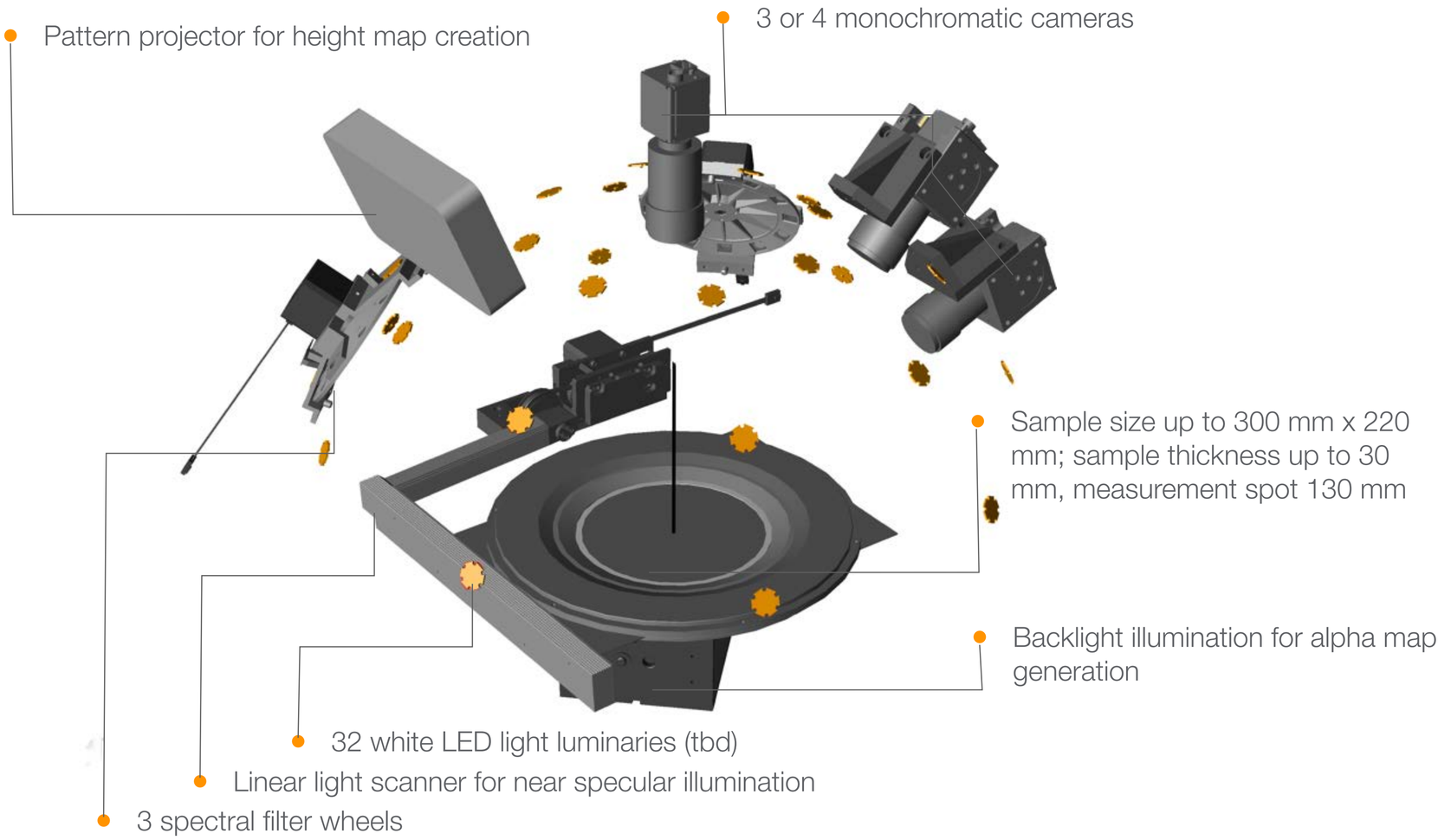




- Sparse BTF **fitted to Carpaint** model (BRDF + BTF)
  - 100 MB data typical
  - 15 minutes typical
- Sparse BTF **fitted to SVBRDF**
  - 20 MB data typical
  - 15 minutes typical

- CPA (car paint)
- SVBRDF normal-map
  - Diffuse albedo map (RGB and spectral)
  - Specular color map (RGB and spectral)
  - Specular roughness map
  - Normal map (which replaces the need for a Bump map as this carries more information)
  - Surface orientation map (to capture anisotropy)
  - Height map (also known as Displacement map)
  - Fresnel map
  - Alpha map

TOTAL APPEARANCE CAPTURE TAC 7 SCANNER



TOTAL APPEARANCE CAPTURE: **THE TAC7 SCANNER**

Dimensions:	• approx. 70 cm x 70 cm footprint
Sample size:	• 300 mm x 220 mm; • hight: up to 30 mm
Measurement spot:	• 120 mm diameter, • ±3 mm depth of field
Pickup:	• 4 monochrome cameras at 5°, 22.5°, 45° and 67.5°
Resolution:	• up to 385 dpi (66µm per pixel) for 5° camera
Capture time and data size:	• measurement typical: 15 minutes | 25 GB raw data for isotropic, medium gloss samples • post processing typical: 15 minutes | 5 - 150 MB processed data depending on computing power and size of region of interest
Illumination:	▸ 32 white LEDs; incident angles: 3 (resolution: 22.5°) x incident directions: 8 (resolution: 45°) ▸ 3 spectral (filter wheel technology) with 8 LEDs; ▸ Linear Light Scanner ▸ Backlight Option (H2/2016)
Structured light:	• 1 structured light projector for creation of hight maps
Supported AxF representations:	• CPA (car paint) • SVBRDF ▸ Diffuse albedo map (RGB and spectral) ▸ Specular color map (RGB and spectral) ▸ Specular roughness map ▸ Normal map (which replaces the need for a Bump map as this carries more information) ▸ Surface orientation map (to capture anisotropy) ▸ Height map (also known as Displacement map) ▸ Fresnel map ▸ Alpha map (-> Backlight Option) ▸ Clear coat maps (Clear coat IOR and normal map)

THE TAC 7 HARDWARE IS A SIMPLIFIED, DOWN-SIZED AND OPTIMIZED DERIVATIVE OF THE DOME TAC SCANNING SYSTEM

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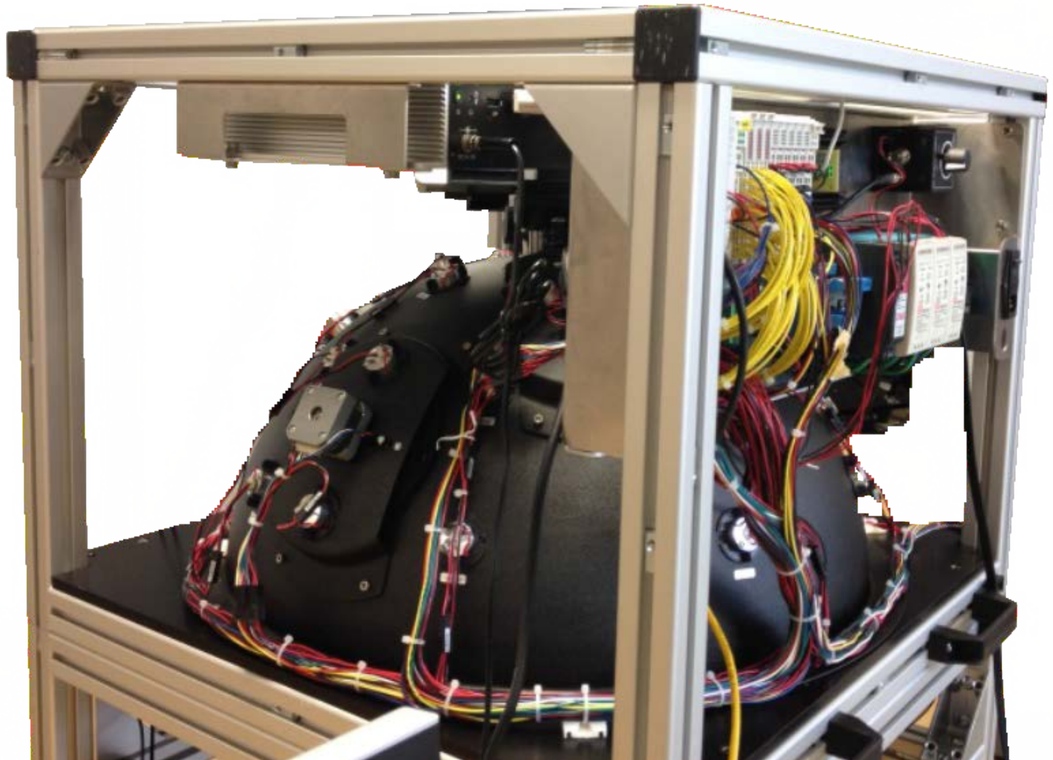
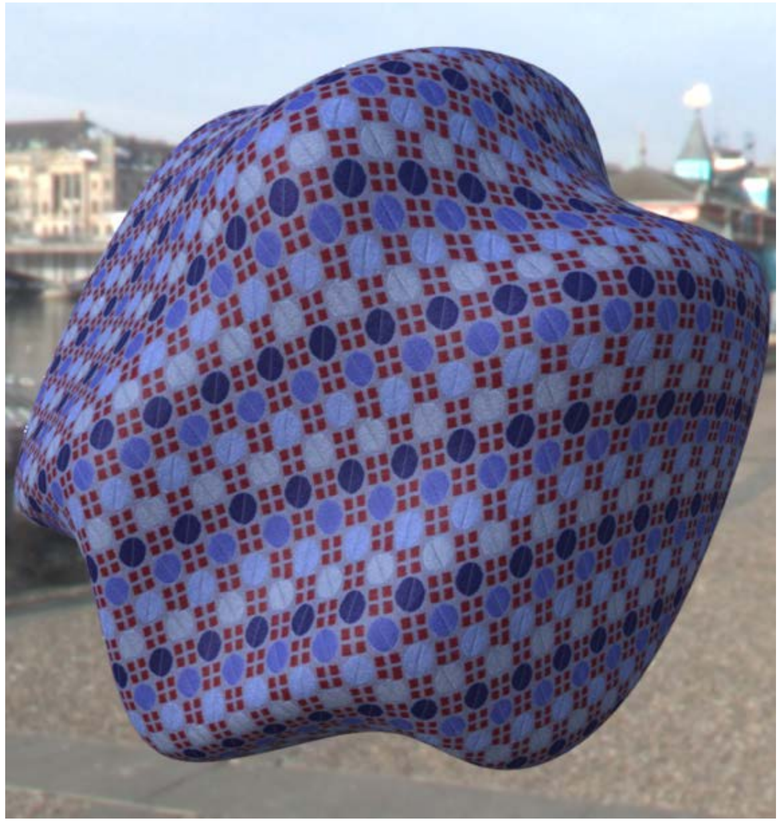
TOTAL APPEARANCE CAPTURE TECHNOLOGY - TAC 7 SCANNER (PROTOTYPE)

- **Diffuse albedo map** (current prototypes are limited to trichromatic color information, will be upgraded to spectral information with AxF 1.3)
- **Specular color map** (current prototypes are limited to trichromatic color information, will be upgraded to spectral information with AxF 1.3)
- **Specular roughness map**
- **Normal map** (which replaces the need for a Bump map as this carries more information)
- **Surface orientation map** (to capture anisotropy)
- **Height map** (also known as Displacement map) (latest feature, currently not used by any rendering application, also our tools like Pantora are not currently make sense out of it)
- **Fresnel map** (AxF 1.1)
- **Index of refraction map** (AxF 1.1)
- **Car paint (CPA)** v1 and v2 (BRDF with 3 lobes and color table + Flake BTF + clear coat)
- **Alpha map** (upcoming feature AxF 1.4)

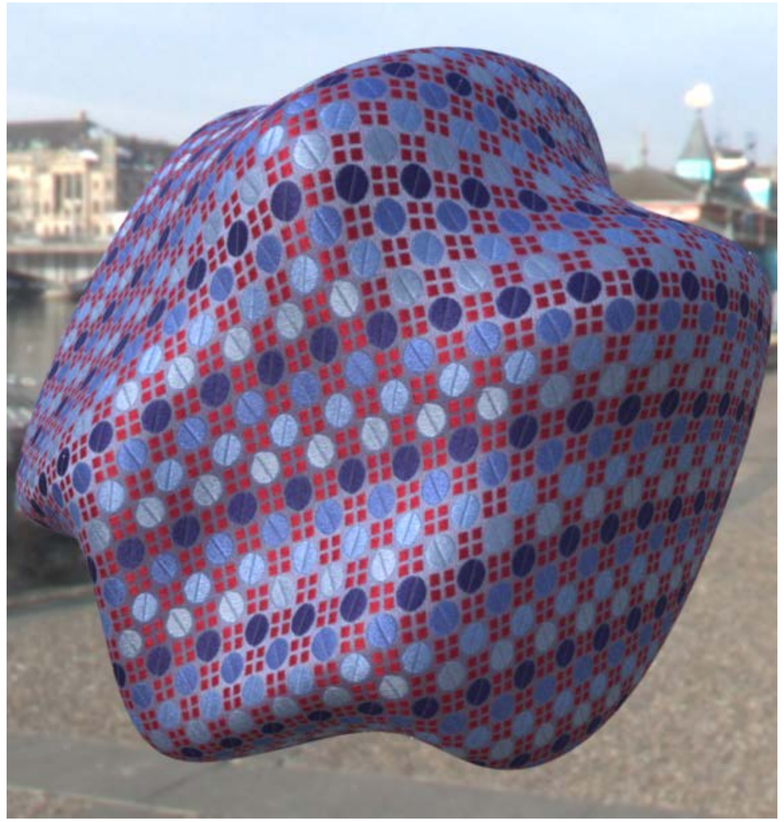


TOTAL APPEARANCE CAPTURE CONVENTIONAL WORKFLOW, TAC 7 AND DOME COMPARISON

Conventional digital material
Isotropic Ward SVBRDF with spatial variation in diffuse and specular color and normal direction



TAC 7 (development prototype)
Anisotropic Ward SVBRDF with spatial variation in all parameters



Dome
Factorized BTF

TAC7 MATERIAL FITTING QUALITY (DEVELOPMENT STATUS OCTOBER 2015)

- Materials used for car interior and exterior show a wide variation. The table below indicates the percentage of materials which can be measured successfully with the TAC7 prototype based on the development status in August 2015. The current prototype excludes CarPaint 2.0 and Fresnel Mapping which will add improvements for certain material classes.

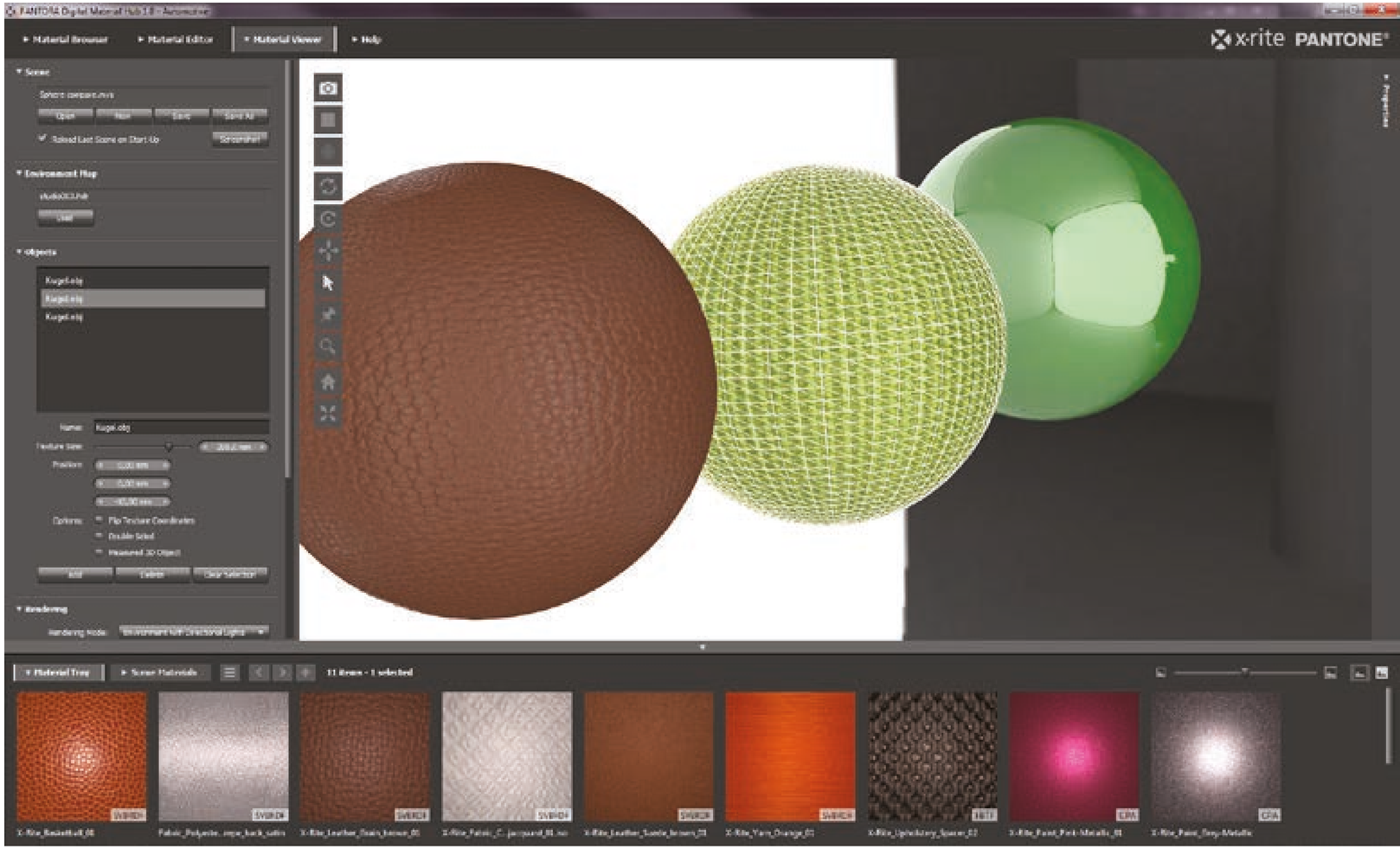
Lacquer Solid	●●●●●○○○○○
Lacquer Metallic	●●●●●●●○○○
Lacquer Pearlescent	○○○○○○○○○○
Lacquer Mother of Pearl	●●●●○○○○○○
Lacquer Interieur	●●●●●○○○○○
Lacquer Rim	○○○○○○○○○○
Lacquer Other	●●●●●●●○○○
Leather	●●●●●●○○○○
Leatherette	●●●●●●○○○○
Alcantara	●●●●○○○○○○

Seat Cover Cloth	●●●●●●●●○○
Plastic	●●●●●●●●○○
Film	●●●●●●●○○○
Metal	●●●●●○○○○○
Wood	○○○○○○○○○○
Grain	●●●●●○○○○○
Carpet	●●●●●●●●●○
Soft Top	○○○○○○○○○○
Headliner	●●●●●●○○○○
Thread	●●●●○○○○○○

MATERIAL VIEWER | CAR PAINT

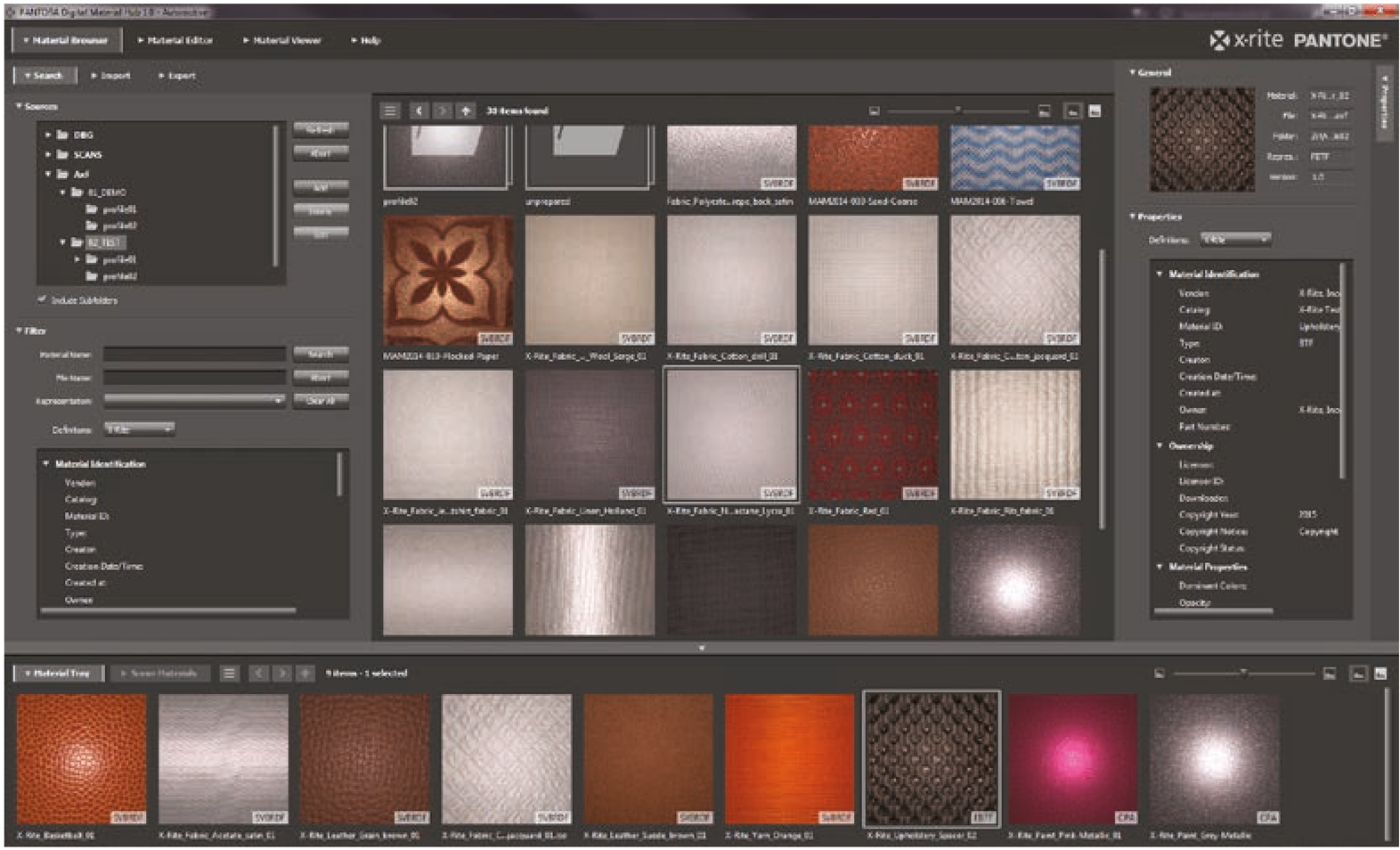
- PANTORA, a desktop computer application, is a component of X-Rite's Total Appearance Capture (TAC) offering. Acting as a hub between the key components of X-Rite's Digital Material ecosystem, PANTORA connects to various Digital Material sources (instruments, catalogs, databases) and destinations (displays, rendering software, PANTONE SILK), and makes sure that highly realistic, color-accurate, and consistent material renderings can be created within different target platforms.

- PANTORA consists of four main modules:
  - Material Browser
  - Material Viewer
  - Material Editor
  - Material Distributor



MATERIAL BROWSER

- The Material Browser module provides various means of finding, acquiring and importing Digital Materials. PANTORA can import Digital Material data as AxF (X-Rite's Appearance Exchange Format) files, directly from instruments, or from local or cloud databases.
- A material browser window displays preview images of the Digital Materials stored in the local database.
- A search tool helps to search materials based on the metadata provided by the AxF (e.g. cotton) and X-Rite's automated keyword index function which generates semantic tags (e.g. light green) for digital materials automatically in the background.
- The user can generate queries or filter materials by specifying different appearance attributes (e.g. color, gloss, vendor, material type, etc.). AxF files are created with the TAC scanning service, with an X-Rite desktop appearance scanner or other instruments.



MATERIAL VIEWER | AUTOMOTIVE INTERIOR

- Within the Material Viewer module a user applies the material to an arbitrary geometry and renders it in a virtual scene. The viewer serves as a calibrated reference renderer for Digital Materials that provides a platform on which to compare rendering results of 3rd-party applications.
- Users can import their own 3D geometry models from 3rd-party CAD applications as well as their own HDR (high dynamic range) environment maps or select from a predefined set of geometries and environments.
- PANTORA offers a highly realistic OpenGL-based renderer. PANTORA's workflow is HDR and is fully color-managed using spectral anchoring all the way through the workflow. Data processing is also either spectrally anchored or fully spectral (depending on the data path and application).
- The scene window allows the user to manipulate (zoom, tilt, position, etc.) the object and camera position. Individual objects can be selected and associated with Digital Materials.

PANTORA MATERIAL EDITING | FACTORISATION (OFF-LINE EDITING)

Digital Material **Creation** 1

Digital Material **Factorisation** 2

Material

- Layer 1
  - Model-function
  - Statistical description

- Layer 2
  - Model-function
  - Statistical description

- Layer n
  - Model-function
  - Statistical description

Digital Material **Editing** 3

Capture measurements

Formulation Database

MA9x measurements

Digital Material 4

Editied Material

- Layer 1
  - Model-function
  - Statistical description

- Layer 2
  - Model-function
  - Statistical description

- Layer n
  - Model-function
  - Statistical description

PANTORA FOR PLASTICS

1

- d:8° data in Color iMatch DB

2

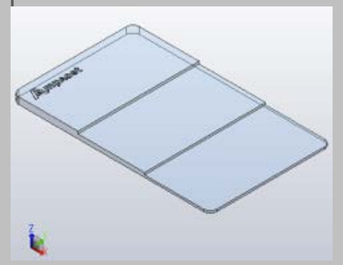
- Appearance data from TAC7
  - surface texture
  - surface gloss

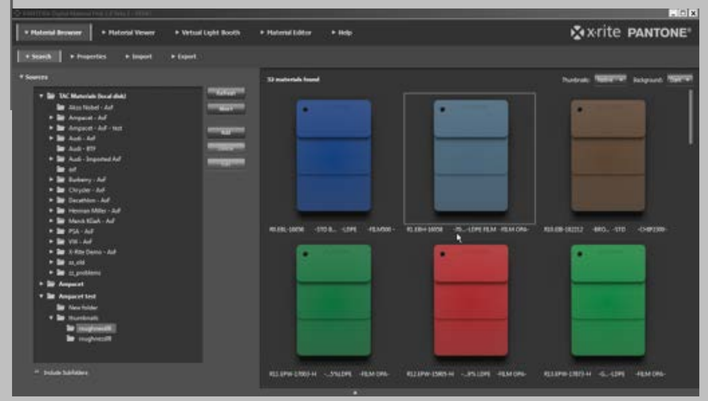
3

- CAD wireframe model of object

4

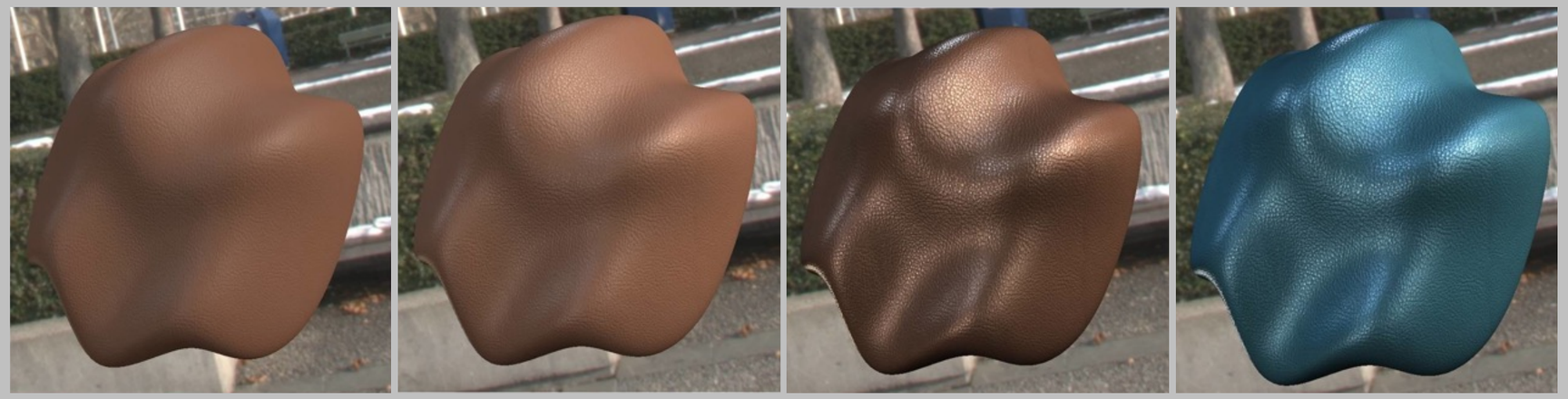
- virtual plastic chips in PANTORA





PANTORA MATERIAL EDITING | CONTRAST AND HUE (ON-LINE EDITING)

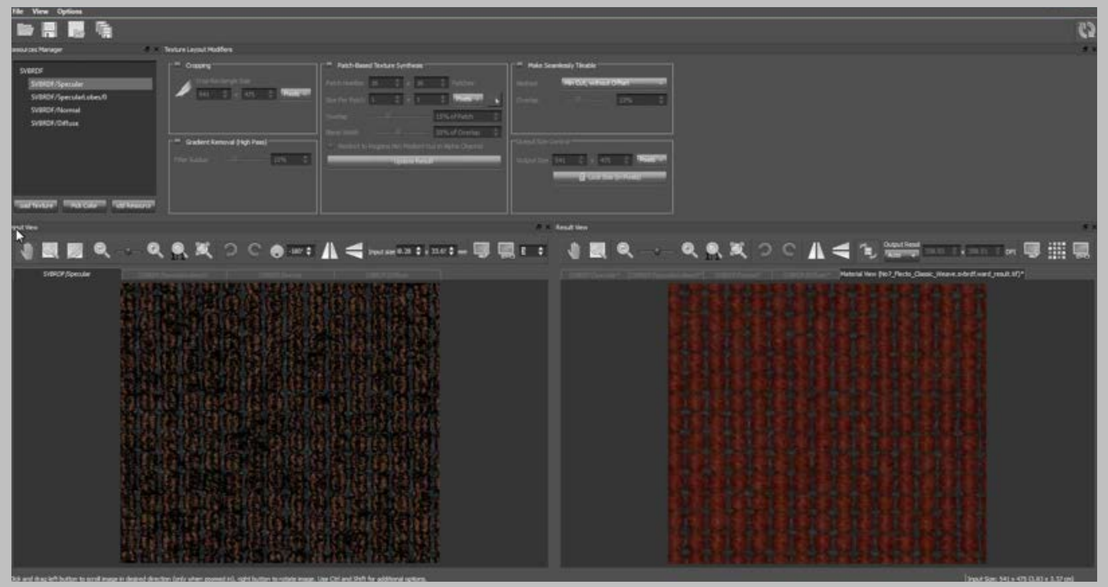
- TAC Digital Materials are “physically correct” and do not require manual “tweaking” in an application
- The Material Editor module allows the user to modify Digital Material attributes in an efficient and physically meaningful way – either manually, via the application user interface, or assisted through instruments.
- In manual mode, a user would, for example, change the gloss level of a surface or the effect pigment concentration of a plastic coating.
- PANTORA supports multi-angle spectrophotometers such as X-Rite’s MA 9x series, as well as image-based color capturing devices like CAPSURE.



Original | Moderate contrast enhancement | Strong contrast enhancement | Hue shift

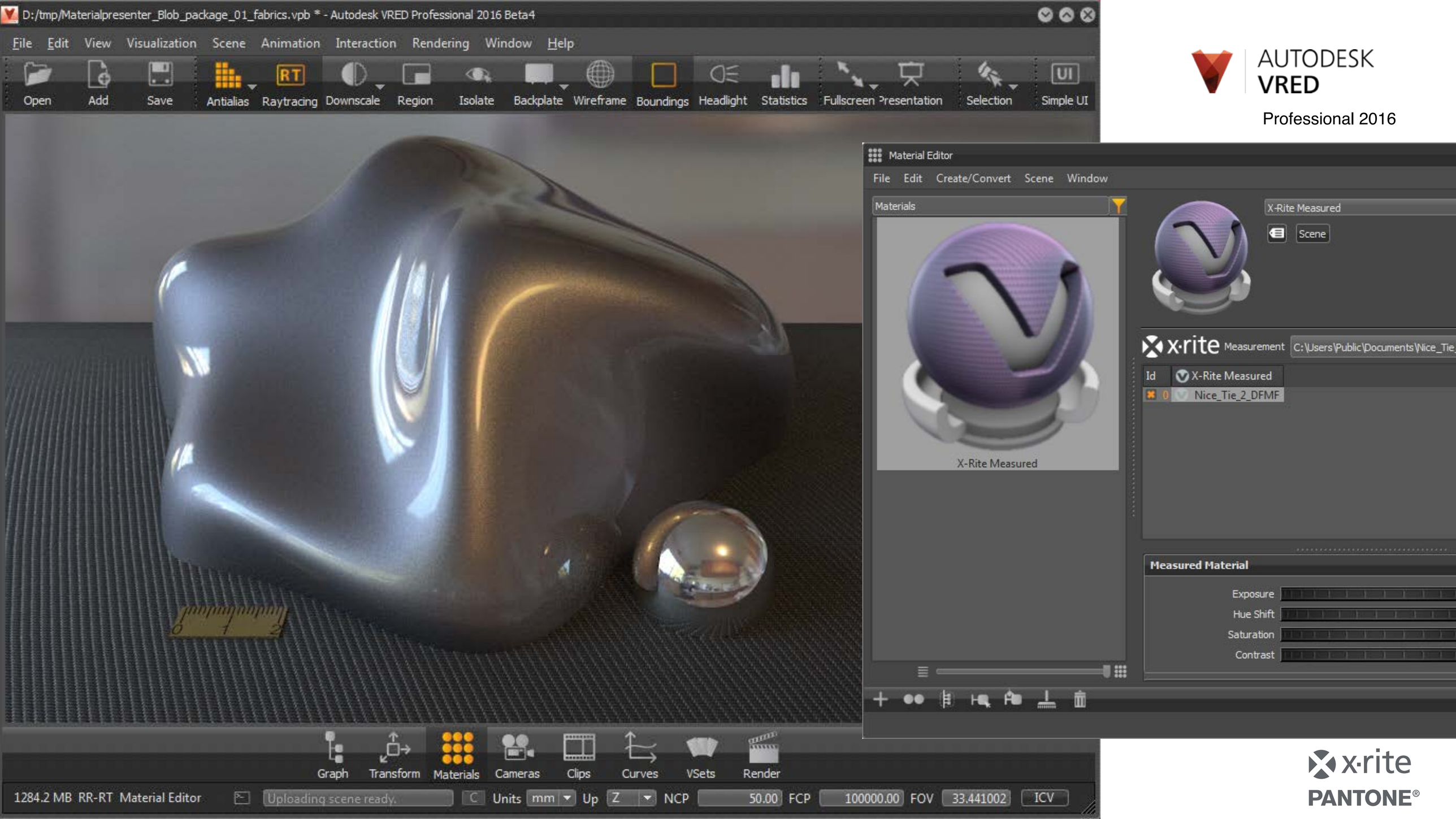
PANTORA MATERIAL EDITING | PATTERN OPTIMISATION (OFF-LINE EDITING)

- The images below illustrate possibilities with the online-editing functionality of PANTORA. On-line editing is performed in the CPU or GPU shader and results are visible in real time in the selected scene.
- Offline-editing operations shown in a preview window (processing is done off-line)
- Texture tool is used to create large textures from small scans using advanced quilting and synthesis algorithms. - Highly automated and can operate not only on bitmap layers but also directly on full appearance data (e.g. BTFs).



TOTAL APPEARANCE CAPTURE: **THE VIRTUAL LIGHT BOOTH**

Illumination:	▸ **D65 diffuse illumination** “SPLQC Class” ▸ **6500K LED point light** (for effect pigment evaluation)
Integrated Virtual Light Booth:	▸ **High Brightness Display** 47”, 5000 cd/m2 ▸ **X-Rite “Full Immersion Technology”** (Patent Pending) ▸ Fully integrated display, dynamic real-time visualization, fully controlled and synchronized material appearance, synchronized sample position (real to virtual sample), synchronized virtual light booth perspective (to observer position) and seamless “round edge” real-to-virtual transition
Render Engine:	▸ **X-Rite “name”** render engine (mview, TAR, GL, AGL, TAGL, RTM) ▸ Real-time engine based on OpenGL, optimized for rendering of virtual materials ▸ **X-Rite Color Pipeline** fully controlled, including ▸ 10 bpc color control, dynamic “observer position dependent” display profiling and real-time consideration of ambient light
Sensors & Controls:	▸ **Face Tracking** and **Sample Tracking** sensors ▸ **Ambient Light Tracking** i1Pro sensor ▸ **Luminaire** (i1Pro) and **Display** (i1D3) **Consistency Control** Sensors ▸ **Turntable** to rotate physical sample, ▸ **Hydraulic Height Adjustment** to automatically adapt to observer height
User Interface:	▸ 13.3” Touch Screen Monitor, demo & evaluation or evaluation & approval workflow
PC & Data Interface:	▸ Embedded Workstation with pre-installed VLB software incl. full VLB calibration data ▸ Point-to-point Gigabit Ethernet connection to external PC running Pantora software for exchange of virtual materials and virtual objects to evaluate materials ▸ Key-locked Gigabit Ethernet port for service and SW updates
Dimensions	▸ H 1810 mm x W 1160 mm x D 750 mm
Weight:	▸ 180 kg



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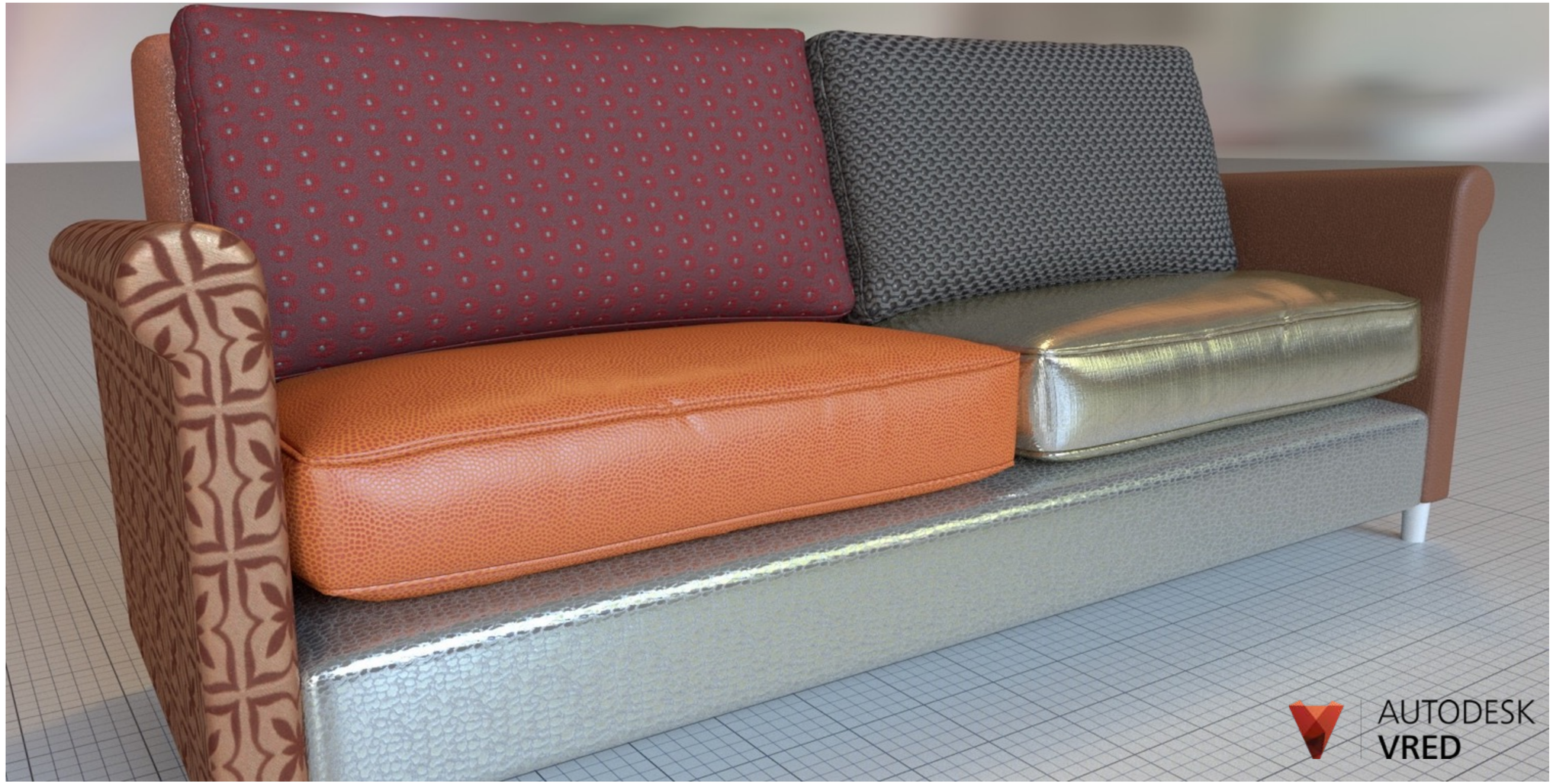
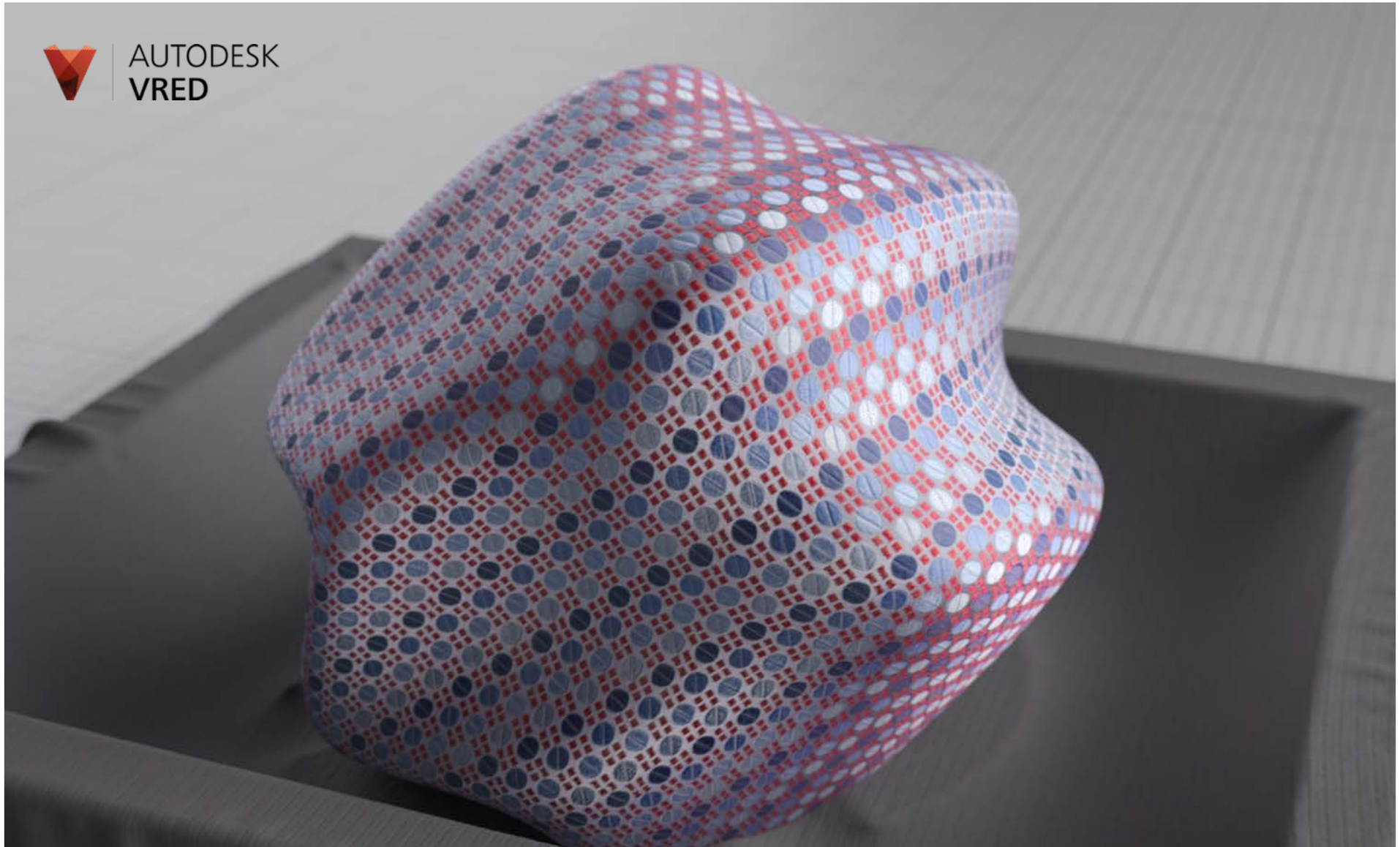
X-RITE DIGITAL MATERIALS IN AUTODESK VRED



X-RITE DIGITAL MATERIALS IN AUTODESK VRED



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QUESTIONS ?

MORE INFORMATION IS AVAILABLE ON OUR WEBSITE:
xrite.com/total-appearance-capture

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