



# ICC DevCon 2020

## Total Appearance Capture And Reproduction

James Vogh



THE FUTURE  
OF COLOR  
MANAGEMENT



# The Future of Colour Management

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## **Total Appearance Capture And Reproduction**

James Vogh

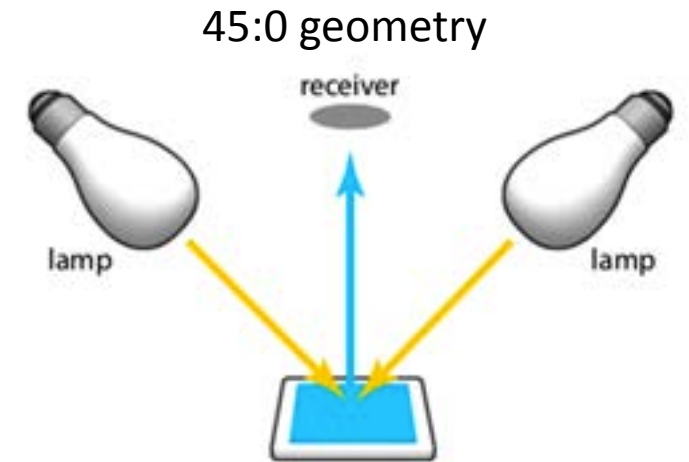


# Introduction

- Total appearance and iccMAX
- Measuring appearance with X-Rite Pantone instruments
  - TAC7
  - MetaVue
  - MA-T12
- Representing appearance data
- Creating iccMAX profiles with appearance data

# Typical Steps to Build a v2 & v4 Print Profile

- Print color patches and measure color patches with a 45:0 spectrophotometer using M0, M1, or M2.
- Save measurements as CxF
- Load CxF and build profile with measurements



# Total Appearance

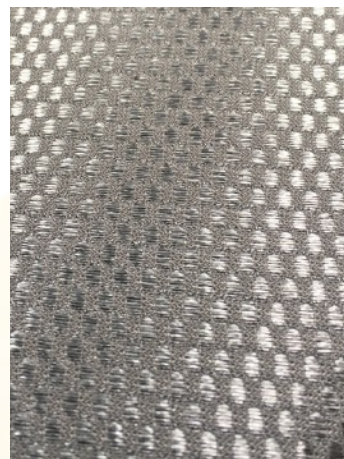
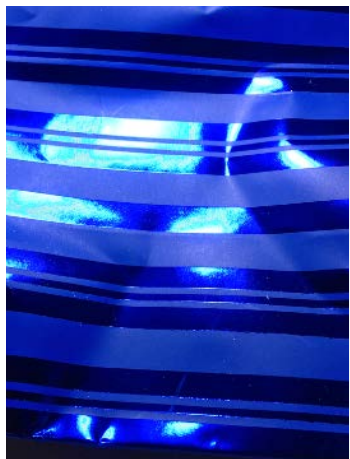
- A 45:0 measurement can work well for some types of surfaces





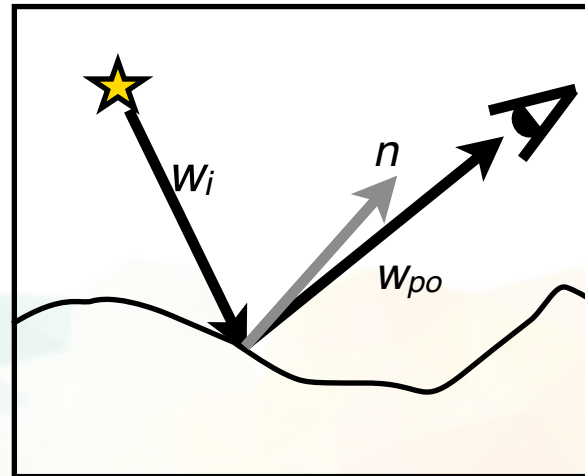
# Total Appearance

- A 45:0 measurement can be inadequate for many other types of materials
- Texture, roughness, gloss, etc.



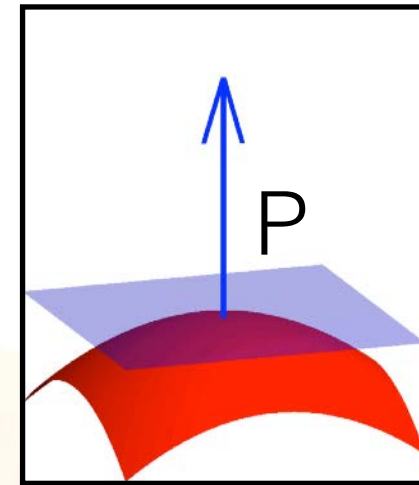
# Total Appearance BRDF

- A Bidirectional Reflectance Distribution Function (BRDF) is a function that specifies the reflectance of a surface for a particular light (position & color) and a viewer (position)



# Total Appearance Texture

- ▶ The surface texture of a substrate can be represented with a normal map
- ▶ A surface normal is the vector that is perpendicular to the tangent plane of a surface at point P

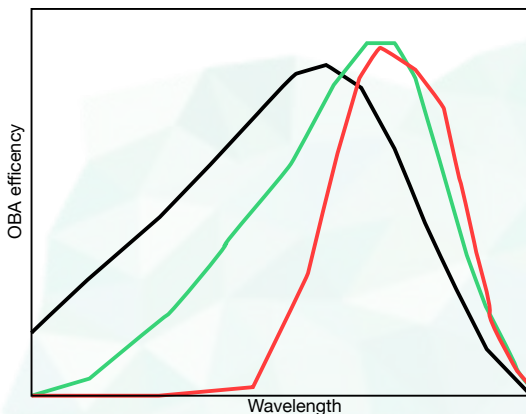


- ▶ A normal map is a set of surface normals across a surface
- ▶ Normal map represents how the normal varies across the surface



# Total Appearance Fluorescence

- Fluorescence excitation can vary from one material to another. Some materials are excited by visible wavelengths.
- M1 & M2 are insufficient to capture these properties.

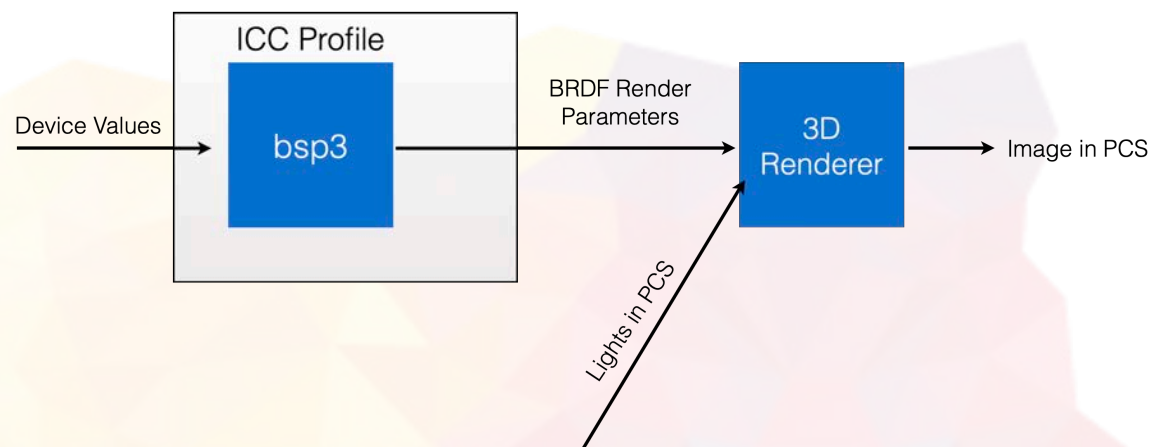
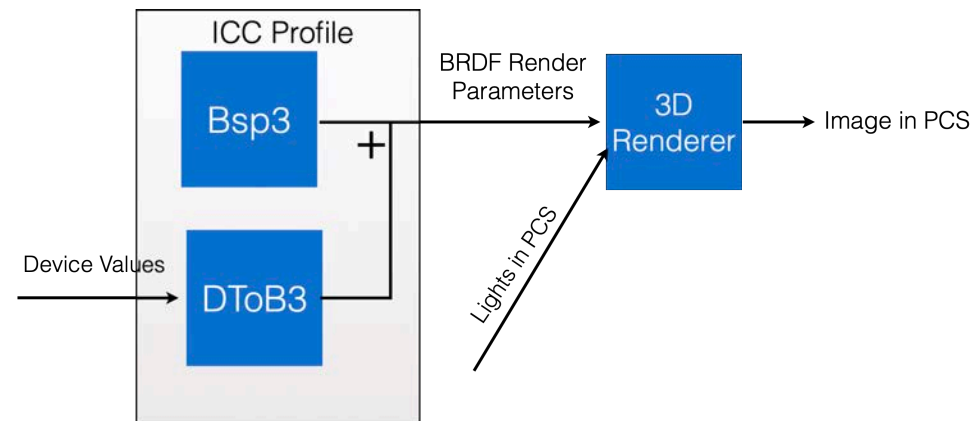


# iccMAX Support for Total Appearance

- iccMAX has support for two types of BRDF representation
  - The BRDF information is in two forms:
    - BRDF parameters for various BRDF models Suitable for use with 3D rendering applications
    - Direct implementation using multiProcessElementType tag
      - Transforms return reflectance when given illumination angle and viewing angle
    - Normal map or height map is used to specify surface texture
- iccMAX has support for Bi-Spectral data in the form of a Donaldson matrix

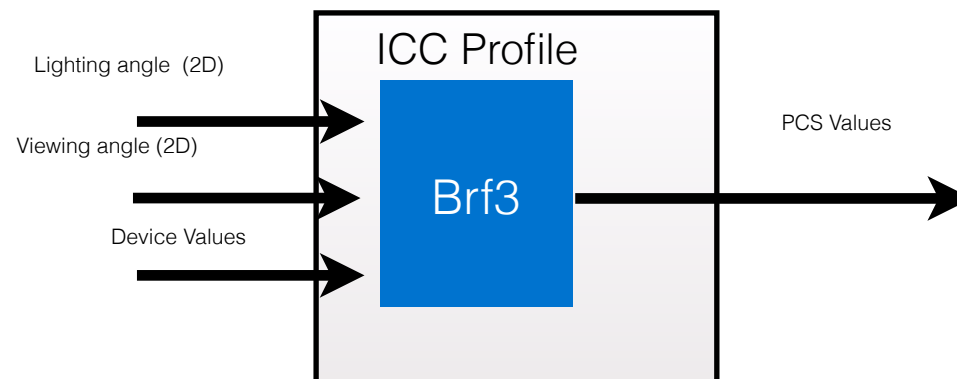
# Parameterized BRDF in iccMAX

- iccMAX supports the following BRDF models
- Blinn-Phong, Ward, Cook-Torrance, and Lafortune
- Two forms of Parameterized BRDF
- Monochrome
  - One set of BRDF parameters for all device values
  - Allows for very simple inclusion of BRDF information in the profile when one set of parameters is sufficiently accurate
- Chromatic
  - Parameters are a function of device values
  - Characterizing printing with a metallic ink would be a good use case for this form
- Can create spectral or colorimetric parameters depending on the type of tag



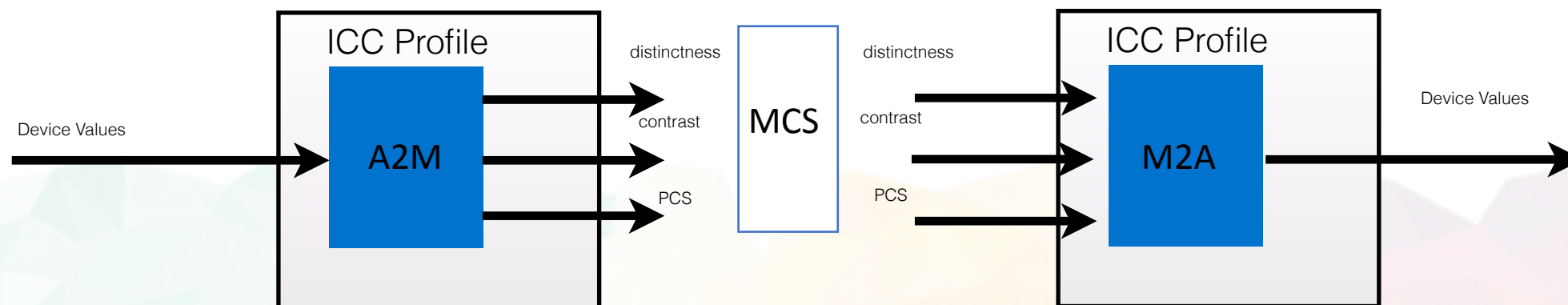
# Direct BRDF Calculation in iccMAX

- Transform is implemented as multiProcessingElement
- Input
  - 2D lighting angle (azimuth & zenith)
  - 2D viewing angle (azimuth & zenith)
  - Device values
- Output can be colorimetric or spectral depending on the type of tag



# Reproduction of Appearance

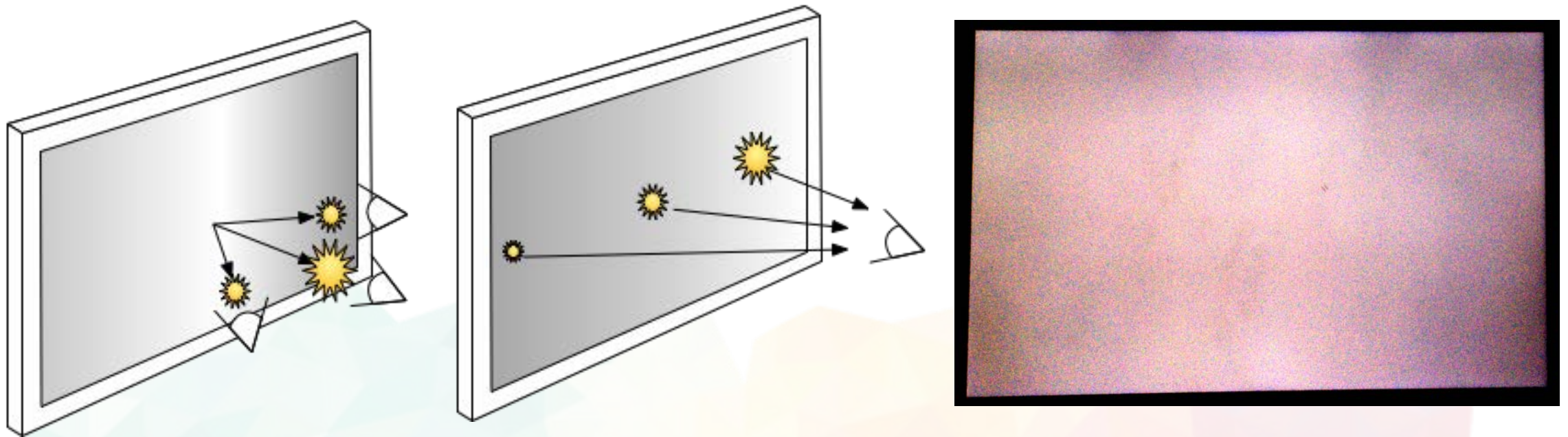
- iccMAX supports the use of multiplex connection spaces
- Multiplex connection spaces can be used to connect two profiles that have compatible appearance spaces
  - Using distinctness & contrast (FERWERDA) for example.





# iccMAX Support for Total Appearance Display

- iccMAX also has support for spatial and angular display profiles.



# How to Measure Appearance

- Look at what can be measured with some current instruments
  - TAC7
  - MetaVue
  - MA-T12

# TAC7

- The TAC7 scanner captures and stores color, texture, gloss and other surface appearance characteristics of physical material samples.





# TAC7 Measurement Technology

Structured light projector

4 industry-grade cameras

Spectrophotometer

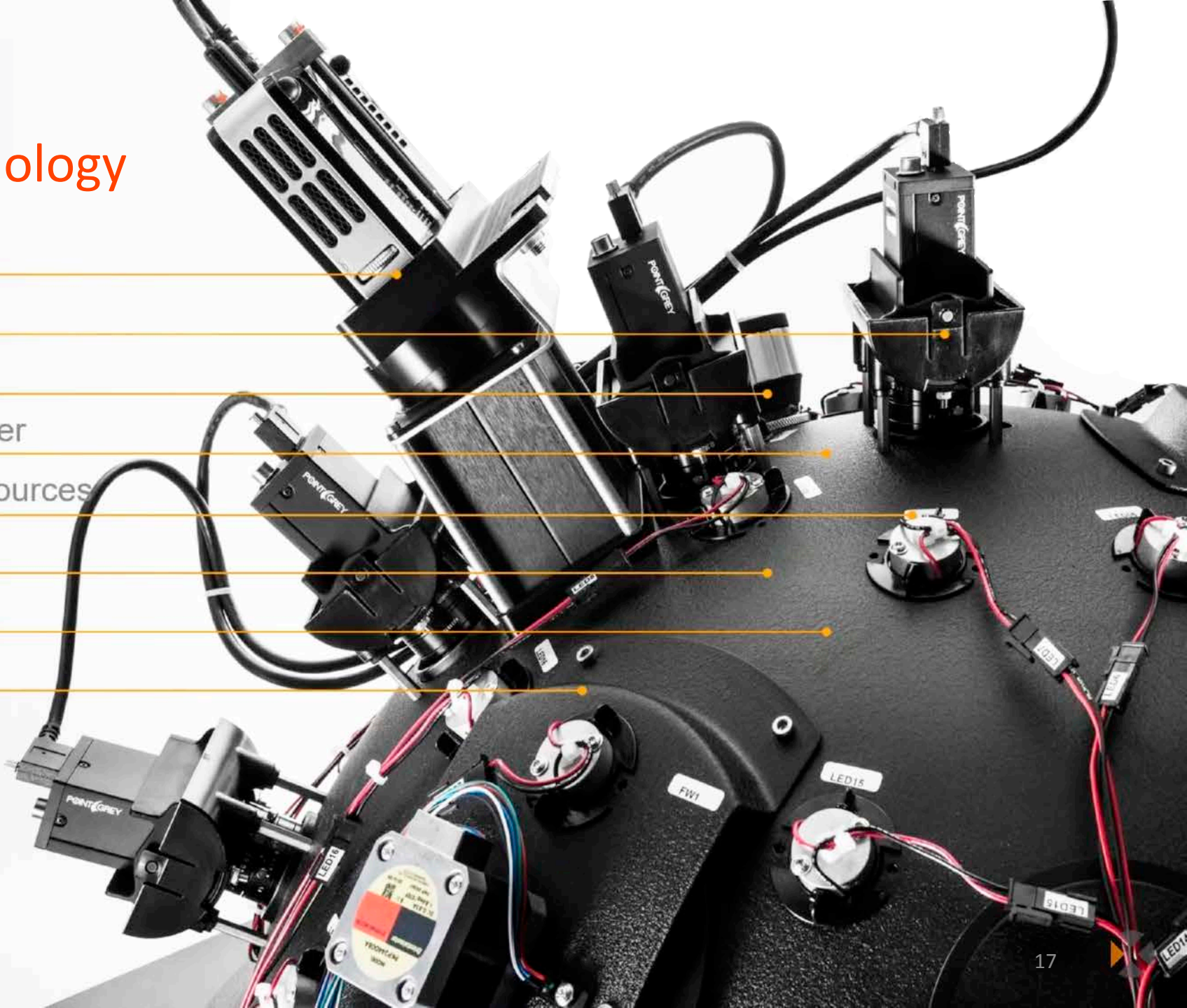
Variable linear light scanner

32 white LED point-light sources

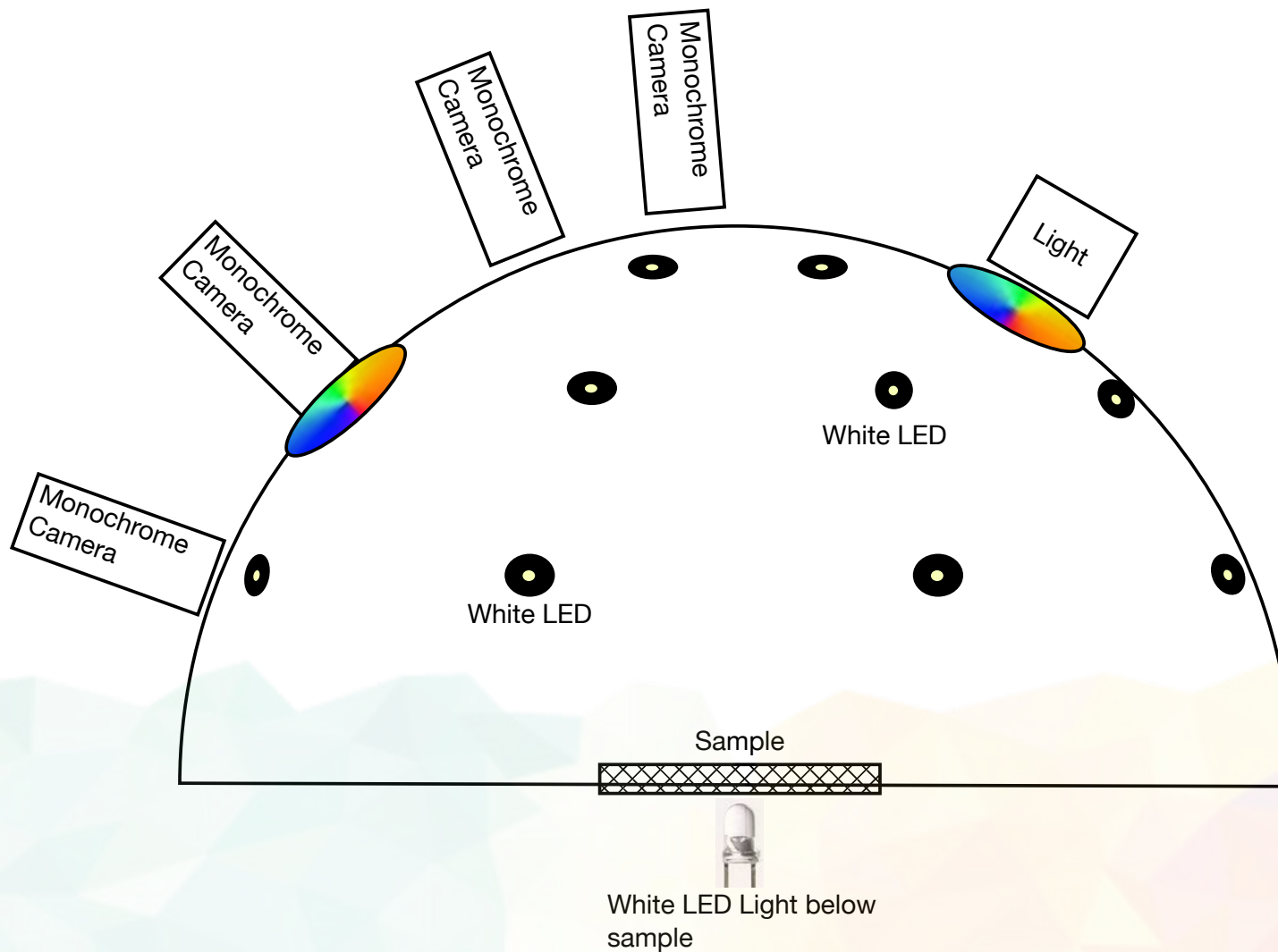
Backlight module

Rotation stage

8 spectral light sources



# TAC7

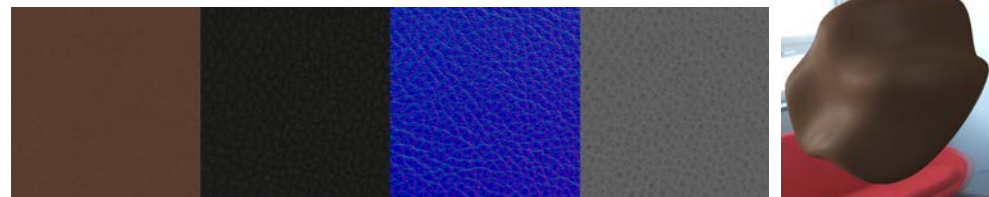




# TAC7

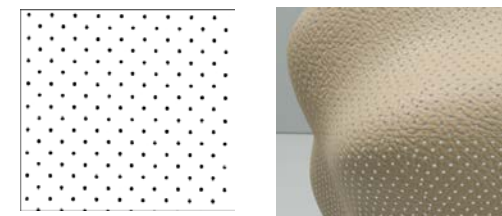
## TAC7 Data – SVBRDFs

Basic



Diffuse color    Specular color    Normals    Roughness

+ Transparency



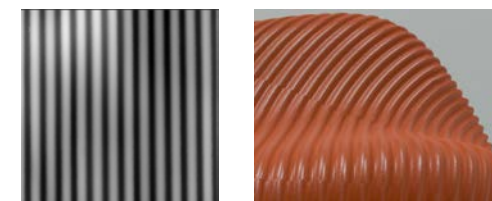
Alpha

+ Coating



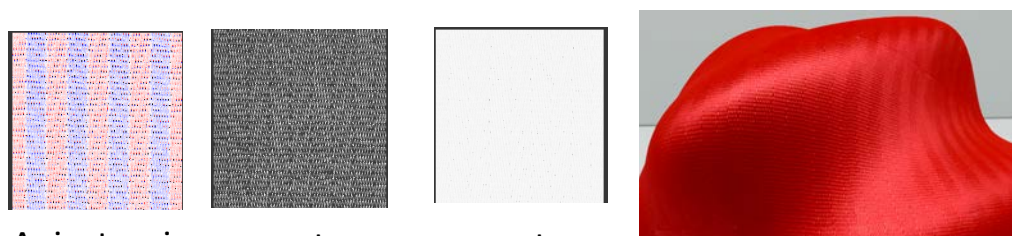
Clear Coat Normals  
("Orange Peel")

+ Displacement

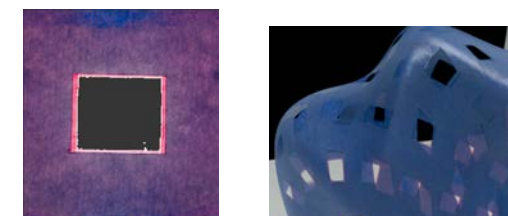


Height

+ Colored Transmission



Anisotropic rotation    X-roughness    Y-roughness



Transmission color

# TAC7 Bi-Spectral Measurement & Colored Transmission

Color wheels over 3 LED lights, UV LEDs, and 1 camera (new)



Camera Filter Wheel

UV LEDs

LED Filter Wheels



# TAC7 Bi-Spectral Measurement

Current TAC7

TAC7 with CAM FILTER WHEEL UPGRADE and UV LEDs.

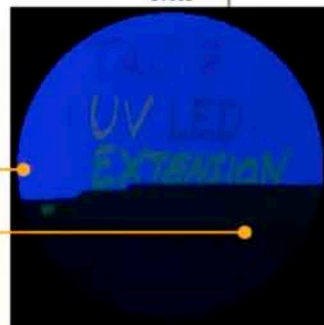
Light27



Light1



UV365



UV365



VIS405



White printer paper with OBAs

Non-fluorescent Munsell chart material for reference

Colors under UV light (captured with camera FW)

# MetaVue

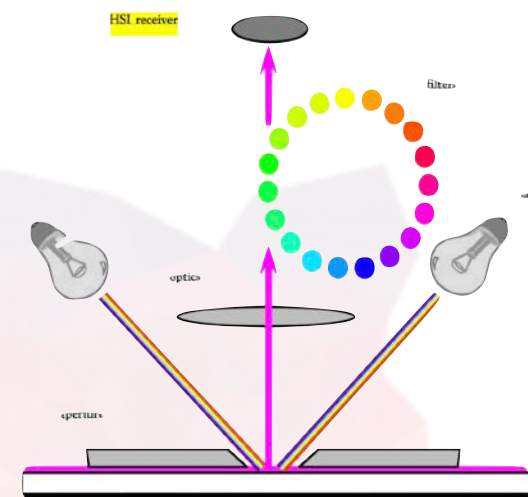


"annular" 45°/0° geometry

- 1 Camera with Filter Wheel
- 3 white LEDs
- 1 Gloss sensor (45°)



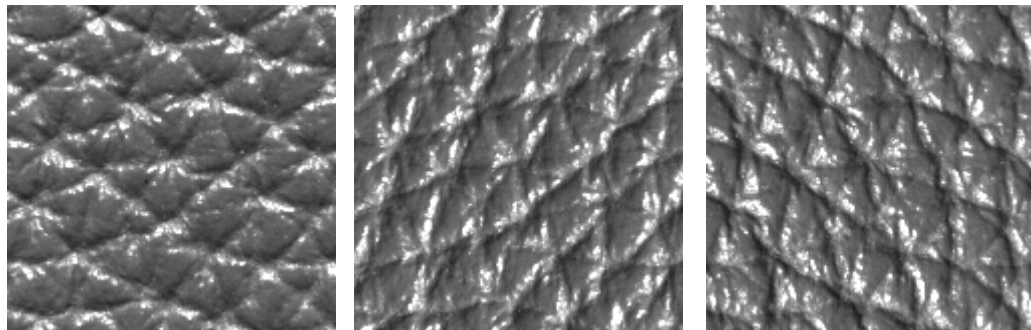
Measurement Spot and Calibration slider





# MetaVue

## Calibrated Data from Device:



“Normal imagecube” 1 - 3

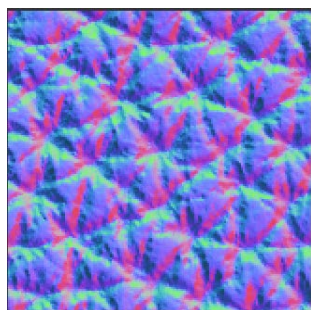


“Spectral imagecube”

30.3

Correlated 60° gloss value

## Processed data:

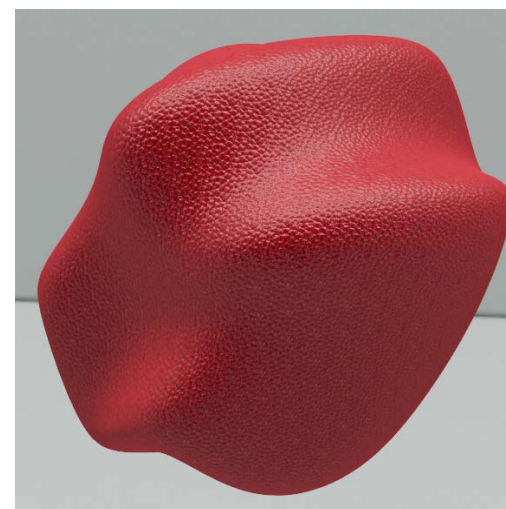


Normals



Diffuse color

+ single specular intensity and roughness values (correlated to 60° gloss)

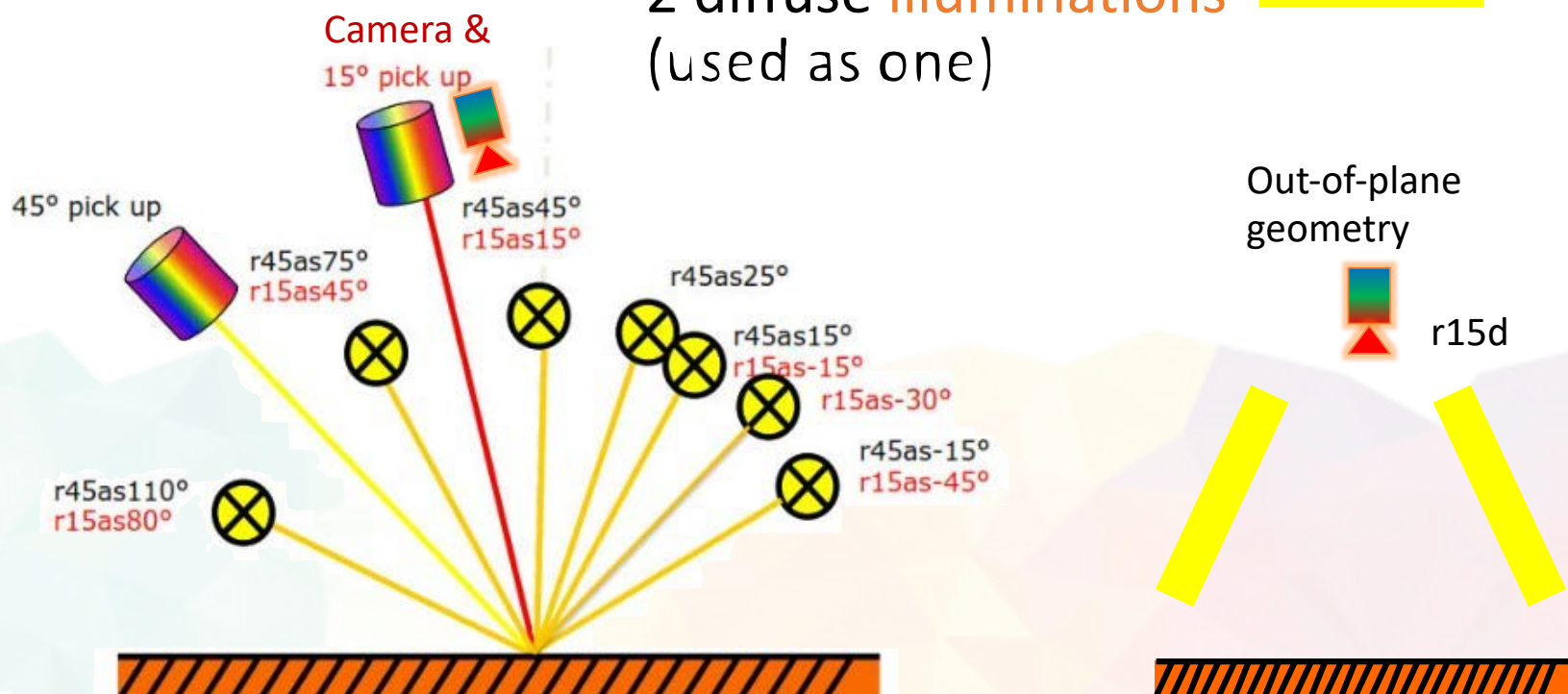




# MA-T12

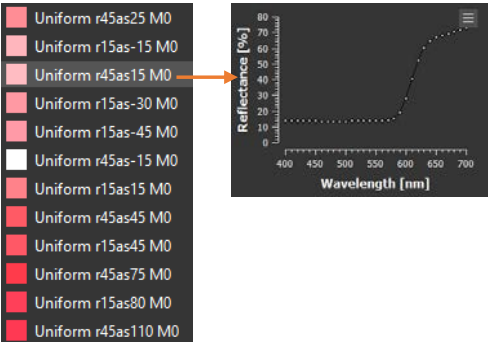


- 1 RGB Camera 
- 2 Spectro pickups 
- 7 white collimated illuminations 
- 2 diffuse illuminations   
(used as one)

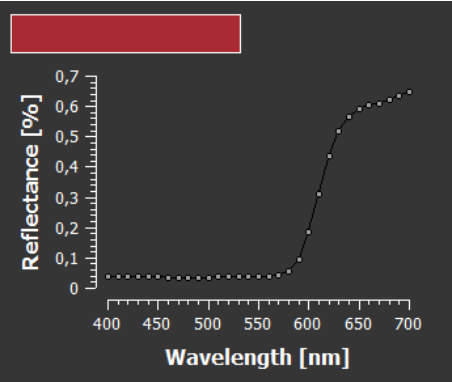


# MA-T12

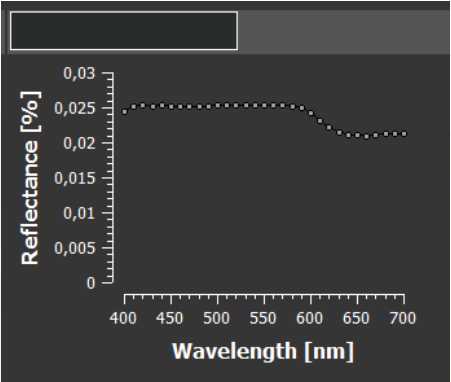
### Calibrated Data from Device:



### Processed Data:



Diffuse color



Specular color

0.1

Roughness



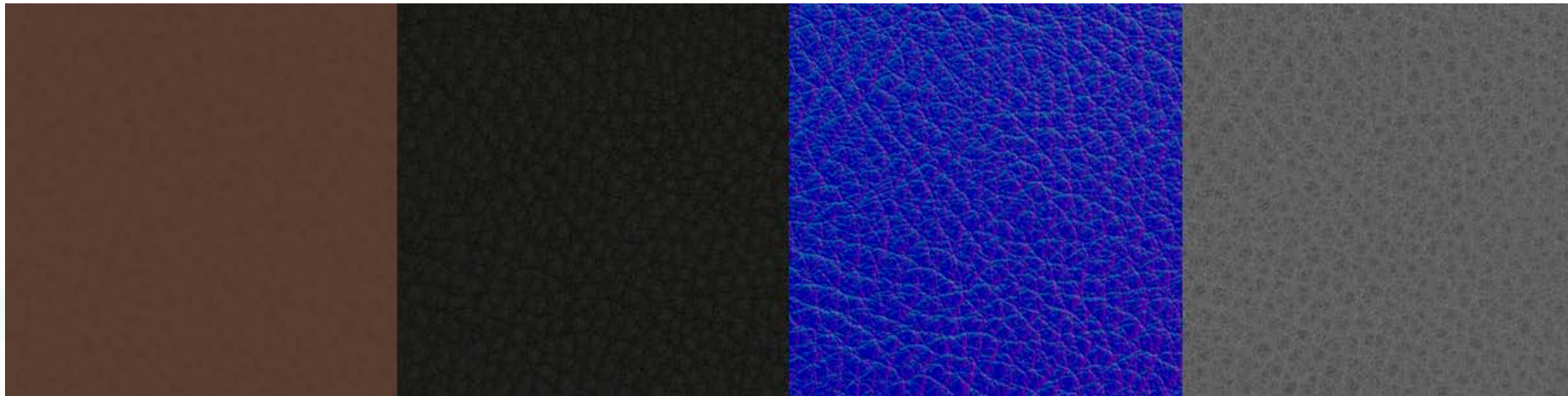
# AxF

- Color exchange Format (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 Organization and has been published as an ISO standard.
  - CxF can be stored in iccMAX as a CxF tag
- Appearance exchange Format (AxF) is a data container to transport complete appearance information of materials across devices, applications and geographies.
  - AxF data is stored as binary data in order to efficiently store the massive amounts of data required to describe the total appearance of a material.
  - AxF is developed as a complement to the CxF format and it is able to store CxF based color information inside to save the color information of a material.
  - AxF allows storing an arbitrary number of different representations for a single material. Different representations of the same material only differ in their technical description of the material.



# AxF

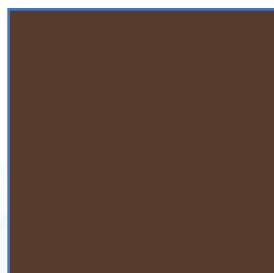
- Isotropic Ward SVBRDF for a measured leather material (from left to right): diffuse, specular, normal, roughness
- AxF SDK can be used to extract BRDF parameters for various models



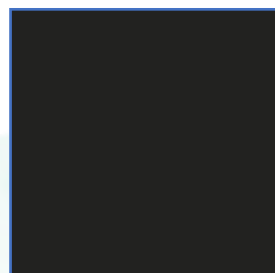


# AxF to iccMAX

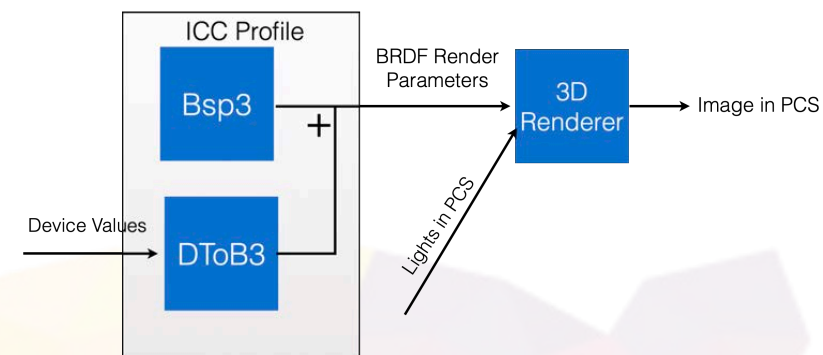
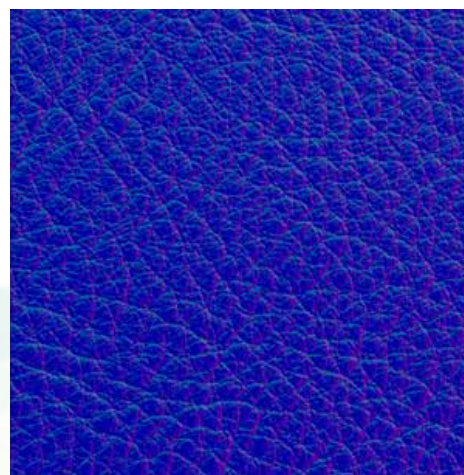
- Simplest iccMAX implementation is to extract normal map and Ward parameters with AxF SDK. Put monochrome parameters in Bsp3 tag and normal map into embeddedNormalImageType tag. DToB3 can be built with traditional 45:0 spectral data.



Diffuse



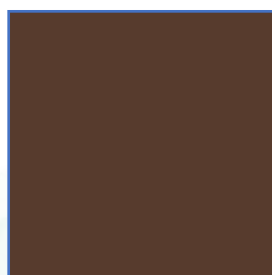
Specular



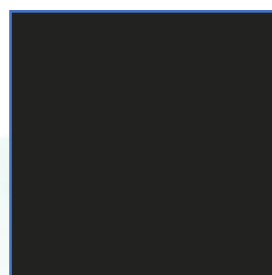


# AxF to iccMAX

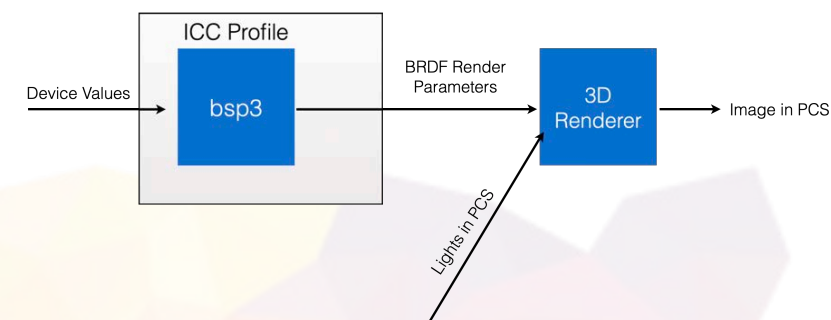
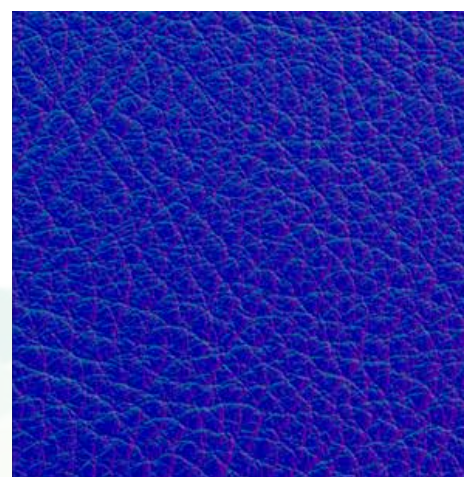
- Next iccMAX implementation is to extract normal map and colorimetric Ward parameters with AxF SDK. Put colorimetric parameters in Bcp3 tag and normal map into embeddedNormalImageType tag. Metallic inks can be approximately simulated with this type of tag



Diffuse



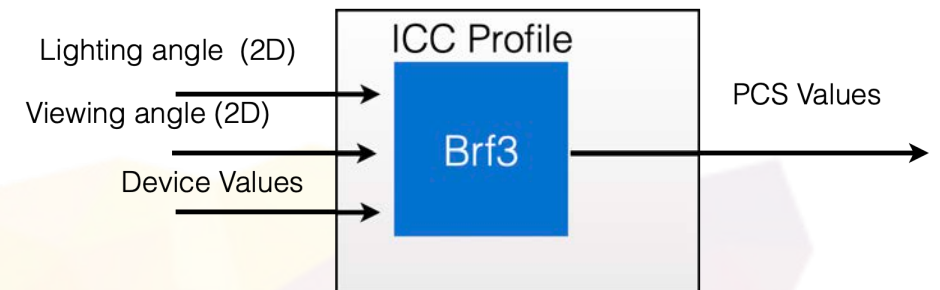
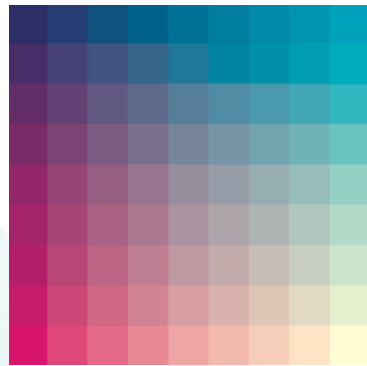
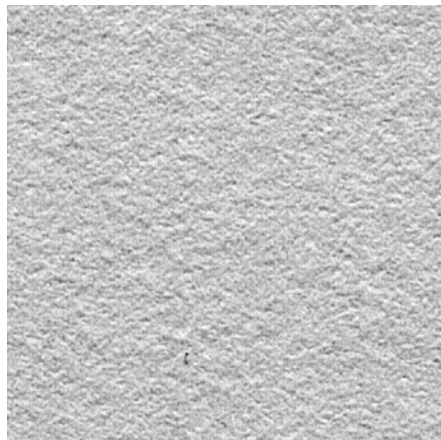
Specular



# AxF to iccMAX

## Direct BRDF (example)

- Print and measure color patches with a device that can measure appearance
- Extract Spatial Varying BRDF from AxF (could get BTF instead)
- Extract normal map and write into embeddedNormalImageType. May want to measure blank substrate for best results.
- Find color patches in the spatial regions.
- Implement a calc element that implements the appropriate BRDF model and interpolates the color space of the device.



# Demo of iccMAX profile with BRDF and normal map

Glossy Paper





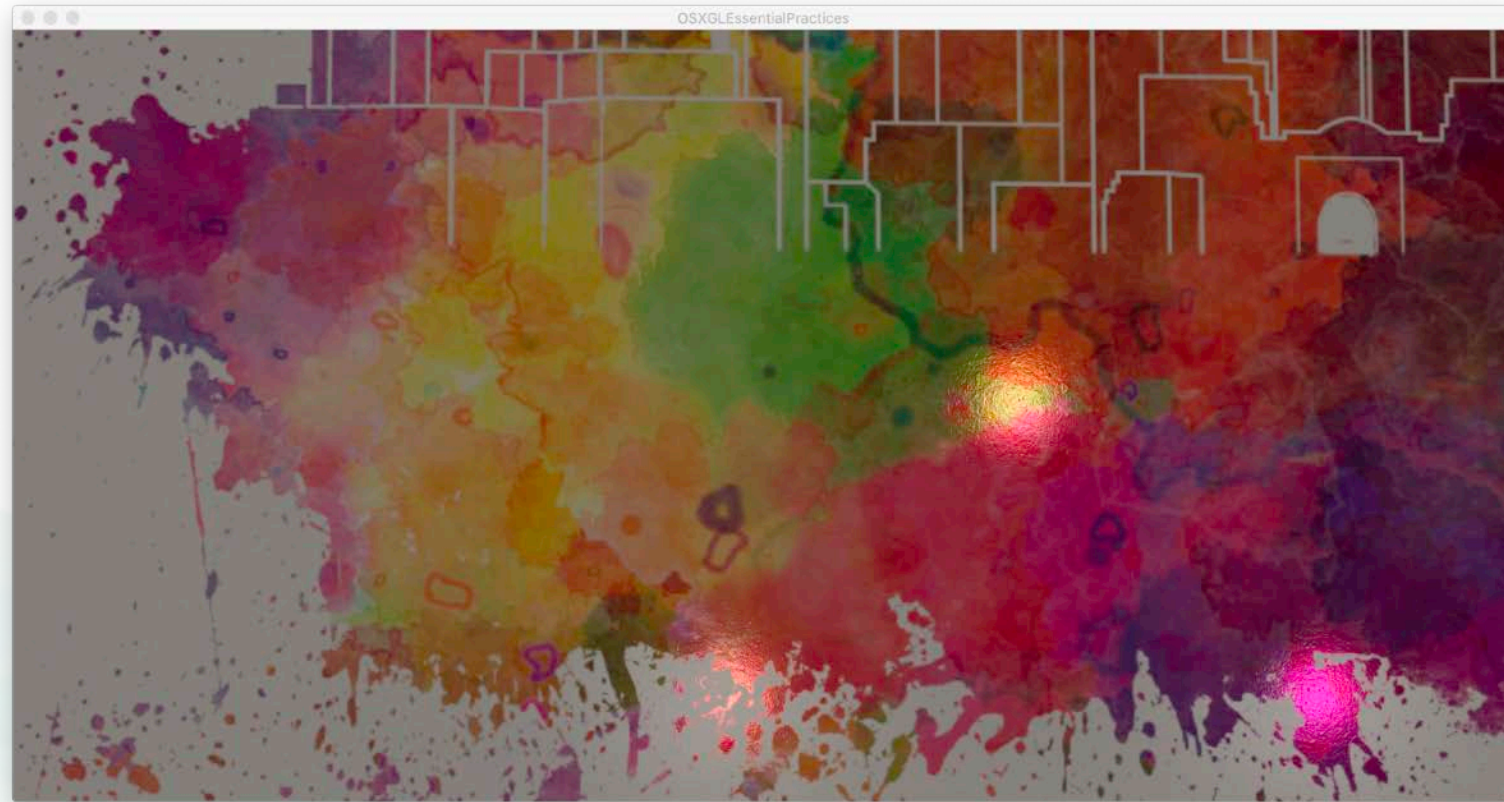
# Demo of iccMAX profile with BRDF and normal map

Matte Paper



# Demo of iccMAX profile with BRDF and normal map

Metallic Ink on Matte Paper



# Conclusions

- iccMAX has been greatly extended beyond just D50 2deg colorimetry
  - Spectral
  - Bi-Spectral
  - BRDF
  - Surface texture
- Existing instruments can measure these appearance properties
- Appearance can then be translated into iccMAX profiles



# Questions