

measuring & modelling BSDF
step 1:
Radiance **plastic, metal, trans** parameters
based on material data

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10th *Radiance* workshop, Lawrence Berkeley National Laboratory

1 basics

- frequently used material: `plastic` et al
- material data and BSDF models in Radiance
- BSDF definition

2 measurement and model of BSDF

- gonio-photometer pgl hardware
- from BSDF data to model parameters
- the *Building Material Examples* web pages
- conclusions

most frequently used materials in Radiance

- basic materials: plastic, metal, trans et al ..

```
void plastic mywood
```

```
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```
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```
5 0.1 0.2 0.22 0.01 0.2
```

most frequently used materials in Radiance

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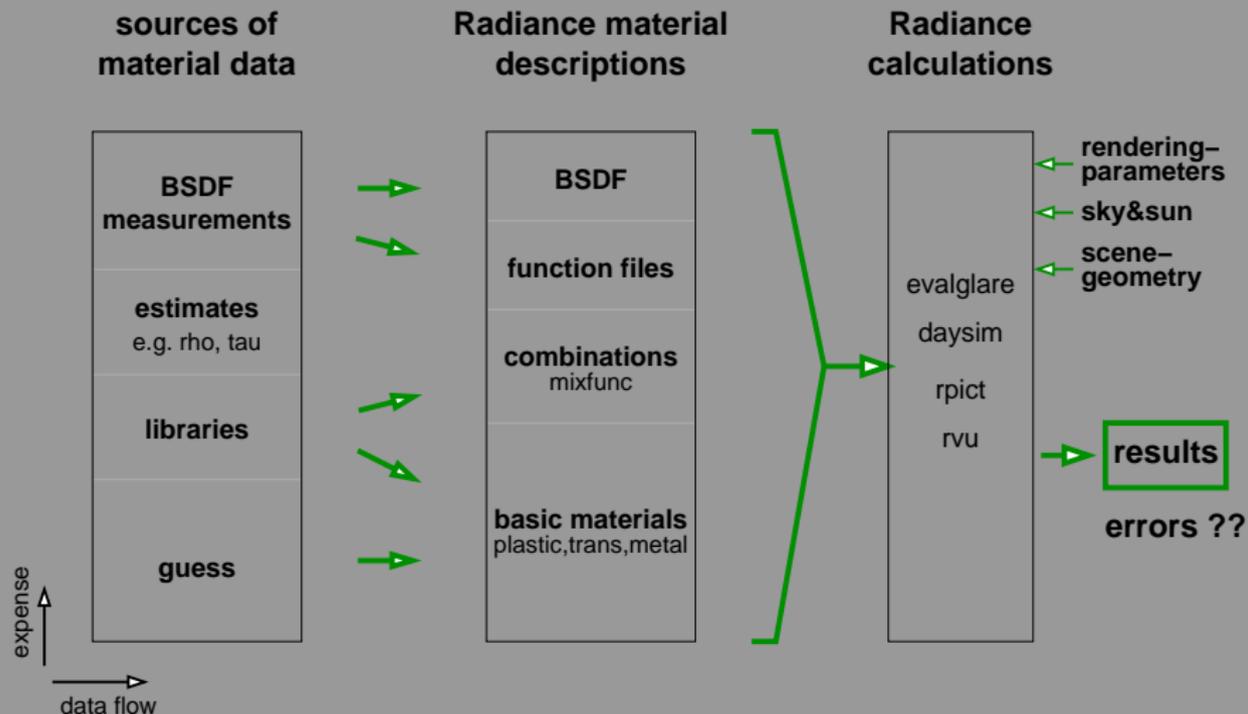
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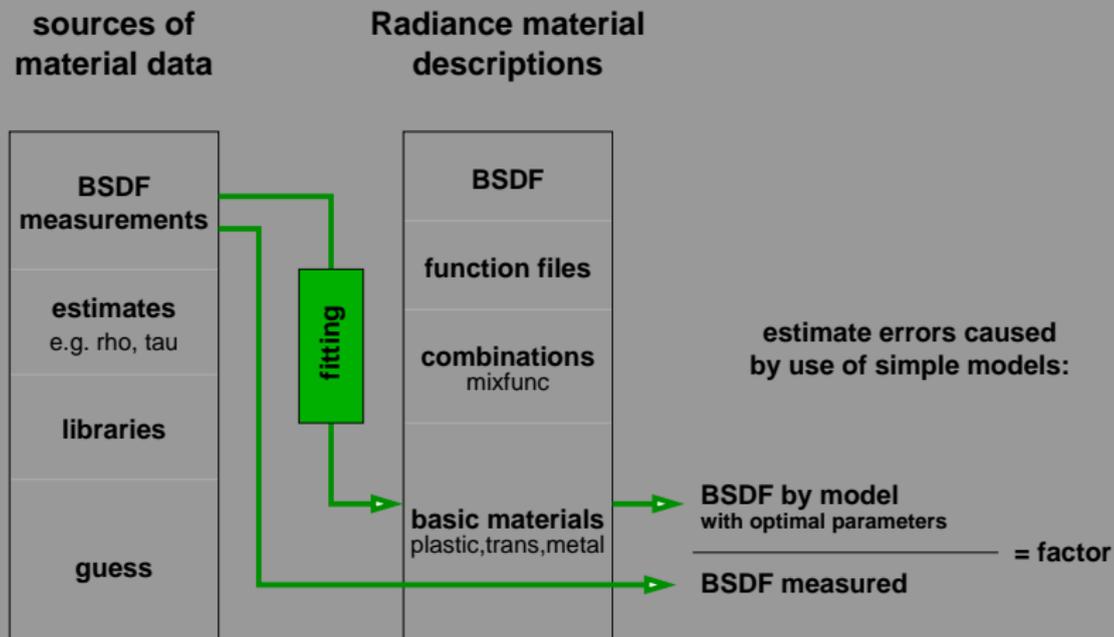
... suitable candidates for comparison to measured BSDF data,

let's have a look at the general framework...

sources and models of material data

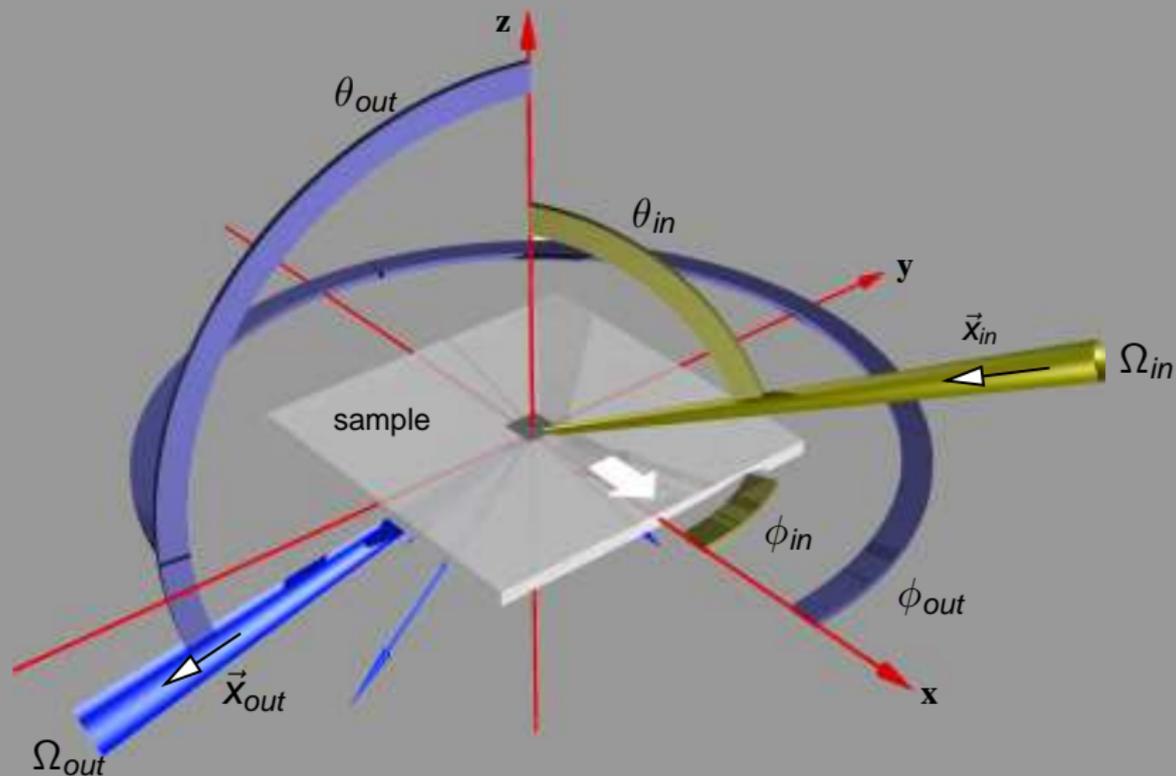


sources and models of material data



... let's do some math and details ...

coordinate system



Definition

$$\mathcal{L}_{out}(\vec{x}_{out}) = \int_{\vec{x}_{in}}^{\Omega_{in}=2\pi} \mathbf{BSDF}(\vec{x}_{in}, \vec{x}_{out}) \mathcal{L}_{in}(\vec{x}_{in}) \cos(\theta_{in}) d\Omega_{in}$$

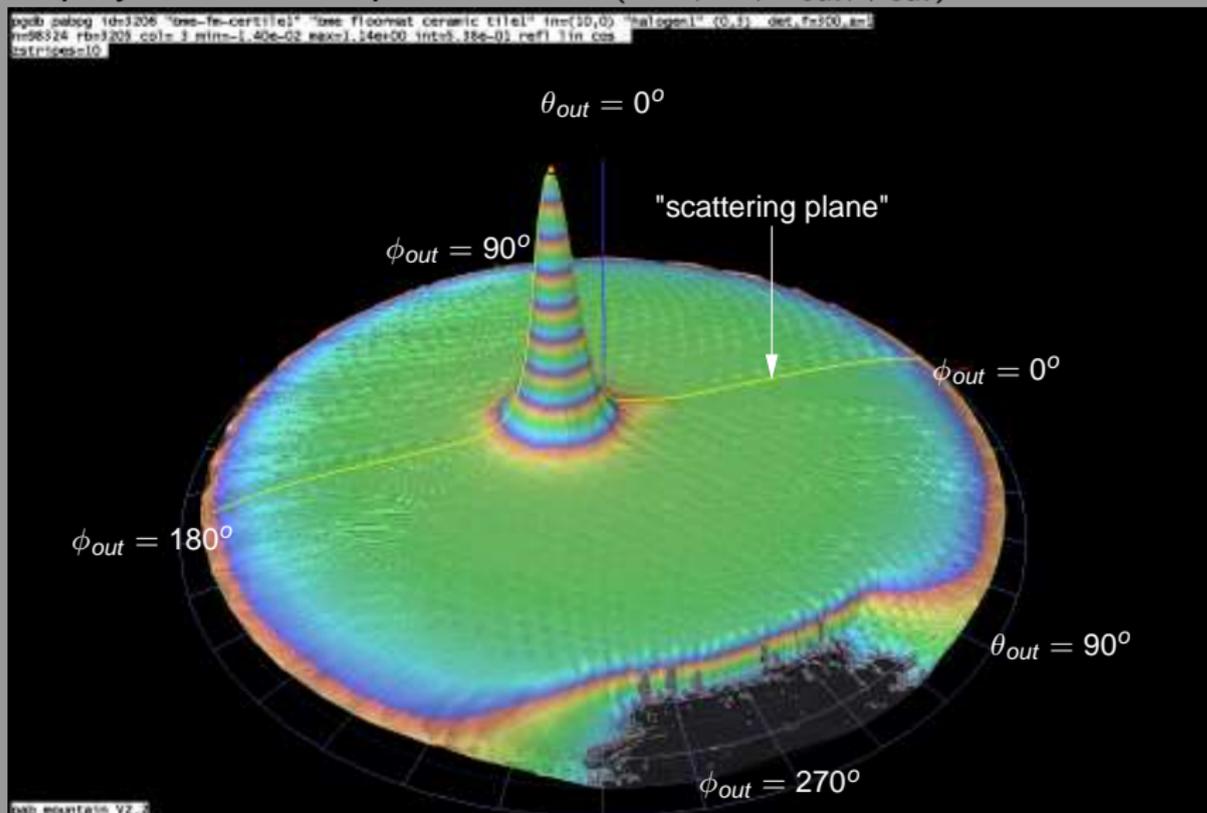
- 4 variables: $\mathbf{BSDF}(\vec{x}_{in}, \vec{x}_{out}) = \mathbf{BSDF}(\theta_{in}, \phi_{in}, \theta_{out}, \phi_{out})$
- $\mathbf{BSDF} > 0$ and may be > 1
- ideal diffuse surface: $\mathbf{BSDF}(\vec{x}_{in}, \vec{x}_{out}) = \mathit{const}$
- transmission: $\tau_{dh}(\vec{x}_{in}) = \int \mathbf{BSDF}(\vec{x}_{in}, \vec{x}_{out}) \cos(\theta_{out}) d\Omega_{out}$
- errors in BSDF propagate to radiance \mathcal{L}_{out}
 \rightsquigarrow errors in glare analysis and irradiance on other surfaces

\mathcal{L}_{out} outgoing, \mathcal{L}_{in} incident radiance, $\int_{\vec{x}_{in}}^{\Omega_{in}=2\pi}$ integral over hemisphere, Ω_{in} inf. solid angle

see pab talk at 2010 workshop for more math

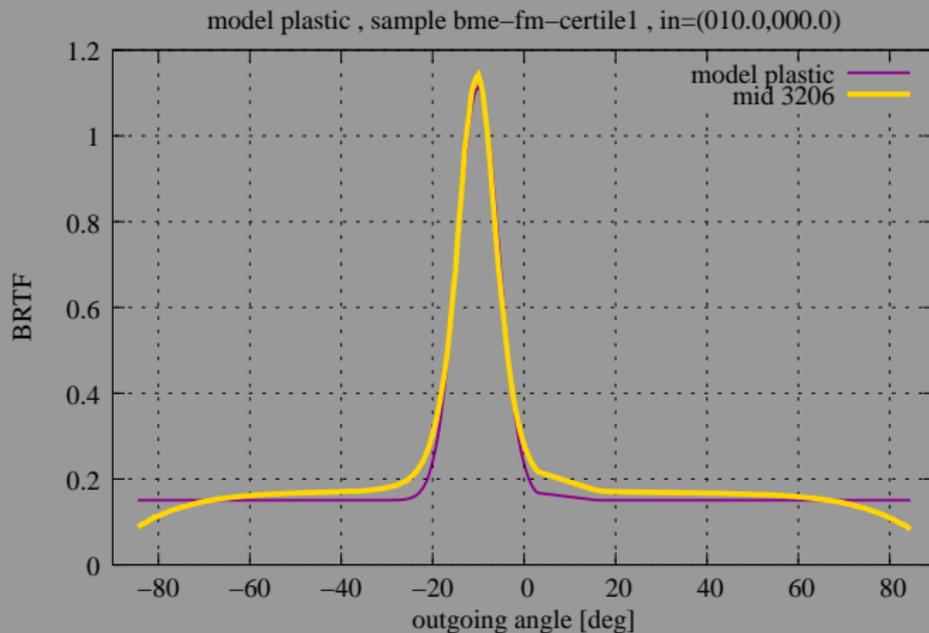
visualising BSDF 3D

display of reflection part of $BSDF(10^\circ, 0^\circ, \theta_{out}, \phi_{out})$



visualising BSDF 2D

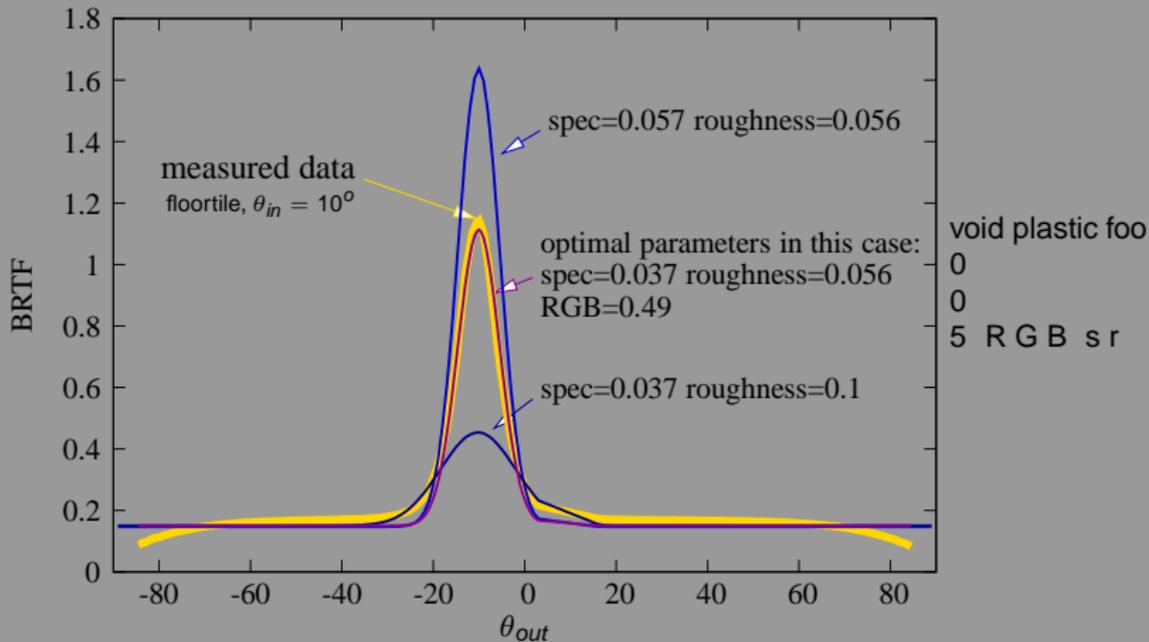
plot of 2D cut along scattering plane:



Radiance BSDF model: plastic

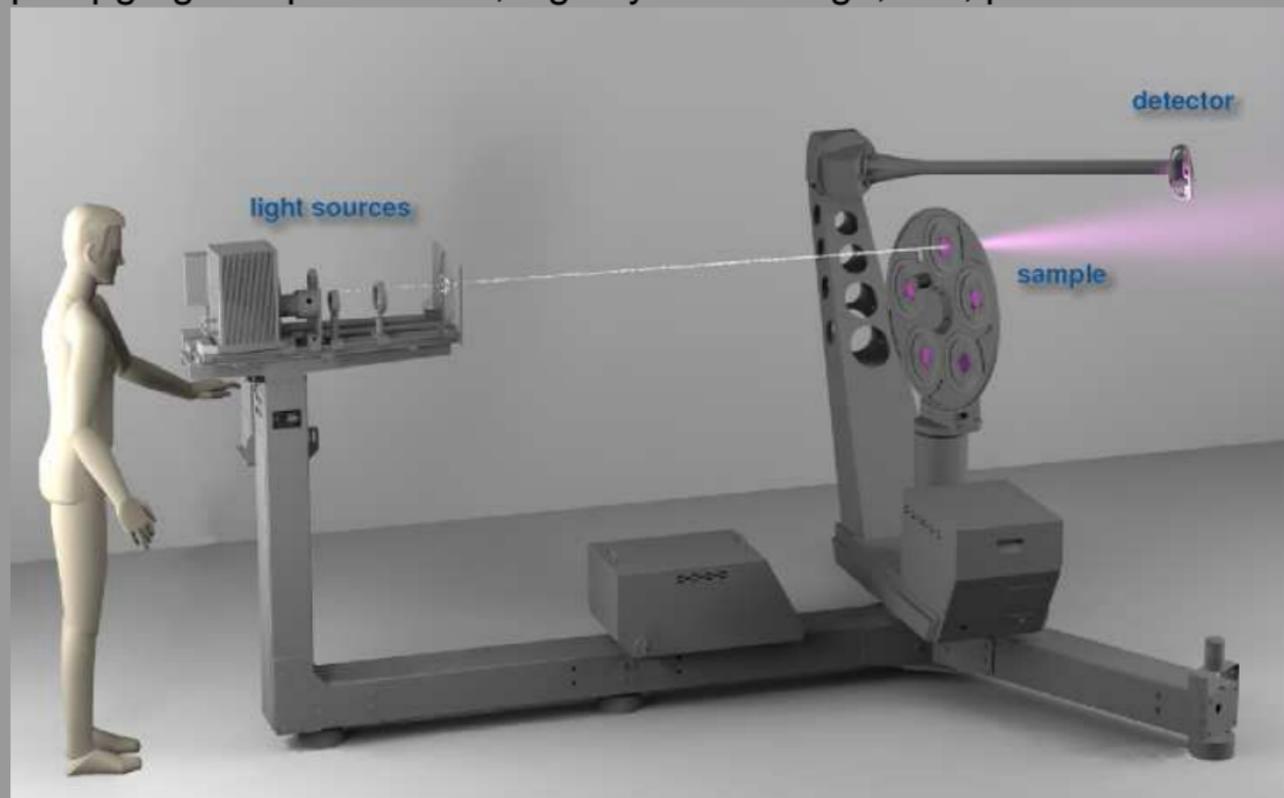
"plastic" Gaussian-Ward BSDF model: constant + Gaussian

$$\approx (RGB - s) + \frac{s}{r^2} e^{-(\theta/r)^2}$$



BSDF data source

pab pglII gonio-photometer, high dynamic range, fast, precise:



side note: currently installed pglI gonio-photometers at SERIS, LBNL, industrial and pab Ltd now accumulated

- approx 600 samples
- around 12000 measurements
- approx 100 million BSDF data-points

fitting process, from data to model parameters

for each material and incident direction (θ_{in}, ϕ_{in}) :

- 1 measure dataset $BSDF(\theta_{in}, \phi_{in}, \theta_{out}^i, \phi_{out}^i), i = [1 \dots \approx 80000]$
- 2 run fit program to find optimal parameters $a_1 \dots a_N$ of model
- 3 \Rightarrow set of parameters $a_1 \dots a_N$ for each incident direction
- 4 get error $\chi := \sum_i (BSDF_i^{model} - BSDF_i^{data})^2$ and min/max factors
- 5 generate graphics, repeat process for next incident angle

generate web-page

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real situation:

- a_i do depend on incident angle
- χ is not negligible (model shape doesn't match data)
- some systematic errors between model and data

technical note:

generic numbering of model parameters for these fits:

```
void plastic myplast
```

```
0
```

```
0
```

```
5 R G B specularity roughness
```

```
    a1
```

```
    a2
```

```
    a3
```

"building material examples" web page

<http://www.pab.eu/bme>

The screenshot shows a web browser displaying the "BME BSRF data" website. The page has a blue header with navigation links: "where to start", "gallery of samples" (which is highlighted), "conclusions", and "get the technical details". Below the header, the main content area is titled "BME BSRF gallery" and contains the text "reflective material models using the radiance plastic model". A grid of 12 small images is displayed, each showing a different material sample on a table with a yellow teddy bear figurine for scale. The samples are arranged in three rows and four columns. Each image has a label above it:

- Row 1: plastic.PI1002CRAP10.381, plastic.aluA-alex1.378, plastic.aluA-el1.379, plastic.bme-fm-carpel1.381
- Row 2: plastic.bme-fm-carliat.343, plastic.bme-fm-chaout.344, plastic.bme-fm-lam1.350, plastic.bme-fm-lam2.352
- Row 3: plastic.bme-fm-mat2.353, plastic.bme-wood1.340, plastic.bme-wp-bwega.342, plastic.bme-wp-wht.341

conclusions from BME measurements:

for practitioners

- "mildly specular" materials at incident angles $< 70^\circ$
typically around 20% error

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- systematic deviations between model and data
 \rightsquigarrow implementing new BSDF models in Radiance ?

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- BME BSDF data available with high resolution, low error

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- BME BSDF data available with high resolution, low error
- results and BME web-pages with details

last slide.

- yours to discover: **www.pab.eu/bme**
- more BSDF math at 2010 pab workshop talk,
plus more measurement details: www.pab.eu/radiance

- happy rendering
- thank you for joining workshop and thanks for your attention

\$RCSfile: brtf-talk-2011.tex,v \$ \$Revision: 1.25 \$ \$Date: 2011/08/24 14:24:31 \$
contact info@pab.eu prior to commercial use.
compiled using L^AT_EX *beamer* class
thanks to Terry&Brian and their sun deck