

Analysis of BS pitch correction for tunnel tilt

JGW-T1605630-v1 - 2016/09/08 - Mark Barton

Preliminaries

The support files RotationsXYZ.nb and RotationsXYZ.m should be installed in one of the directories on the Mathematica path (\$Path).

```
In[2]:= Needs["RotationsXYZ`"]
```

```
In[12]:= ? RotationMatrixXYZBS
```

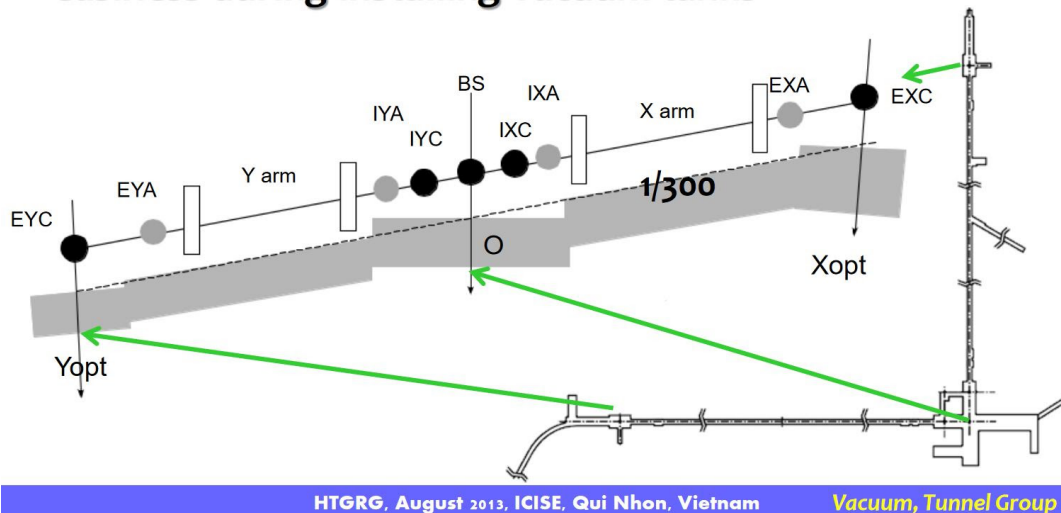
```
RotationMatrixXYZBS[yaw, pitch, roll]
```

Data

Tunnel Design

- Flooring -

- **Slope of 1/300** was selected to drain the water to rivers.
- **Horizontal planes for each station are prepared for easiness during installing vacuum tanks**



Calculation

On the assembly frame the beamsplitting face of the BS faces -Y:

```
In[4]:= BSfaceframe = {-1, 0, 0}; BSfaceframe // TableForm
```

```
Out[4]//TableForm=
```

```
- 1  
0  
0
```

In an ideal IFO the BS needs to be at -45° yaw to this

```
In[5]:= BSangle = RotationMatrixXYZBS[-Pi/4, 0, 0]; BSangle // TableForm
```

```
Out[5]/TableForm=
```

$$\begin{array}{ccc} \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} & 0 \\ -\frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} & 0 \\ 0 & 0 & 1 \end{array}$$

The BS will be rotated by this 45° during installation, putting the BS face in the ideal direction.

```
In[6]:= BSfaceideal = BSangle.BSfaceframe; BSfaceideal // TableForm
```

```
Out[6]/TableForm=
```

$$\begin{array}{ccc} -\frac{1}{\sqrt{2}} & & \\ \frac{1}{\sqrt{2}} & & \\ 0 & & \end{array}$$

However the Y arm is tilted down by 1/300 rad (negative pitch):

```
In[7]:= Yarmangle = RotationMatrixXYZBS[0, -1/300, 0]; Yarmangle // TableForm
```

```
Out[7]/TableForm=
```

$$\begin{array}{ccc} \cos\left[\frac{1}{300}\right] & 0 & -\sin\left[\frac{1}{300}\right] \\ 0 & 1 & 0 \\ \sin\left[\frac{1}{300}\right] & 0 & \cos\left[\frac{1}{300}\right] \end{array}$$

And the X arm is tilted up by 1/300 rad (negative roll):

```
In[8]:= Xarmangle = RotationMatrixXYZBS[0, 0, -1/300]; Xarmangle // TableForm
```

```
Out[8]/TableForm=
```

$$\begin{array}{ccc} 1 & 0 & 0 \\ 0 & \cos\left[\frac{1}{300}\right] & \sin\left[\frac{1}{300}\right] \\ 0 & -\sin\left[\frac{1}{300}\right] & \cos\left[\frac{1}{300}\right] \end{array}$$

So the desired final orientation is

```
In[9]:= Yarmangle.Xarmangle.BSangle.BSfaceframe // N // TableForm
```

```
Out[9]/TableForm=
```

$$\begin{array}{ccc} -0.707095 & & \\ 0.707103 & & \\ -0.00471402 & & \end{array}$$

The required pitch correction on the assembly frame then is $-\sqrt{2}/300$

```
In[10]:= pitchcorr = RotationMatrixXYZBS[0, -Sqrt[2]/300., 0];
pitchcorr // TableForm
```

```
Out[10]/TableForm=
```

$$\begin{array}{ccc} 0.999989 & 0. & -0.00471403 \\ 0. & 1. & 0. \\ 0.00471403 & 0. & 0.999989 \end{array}$$

Applying just pitch correction and the 45° gives the right vertical angle.

```
In[11]:= BSangle.pitchcorr.BSfaceframe // N // TableForm
```

```
Out[11]/TableForm=
```

$$\begin{array}{ccc} -0.707099 & & \\ 0.707099 & & \\ -0.00471403 & & \end{array}$$

Conclusion

The beamsplitting face of the BS should be set to pitch down by $\sqrt{2}/300 = 4.71405$ mrad on the assembly frame.