IWAA 2024
INTERNATIONAL WORKSHOP ON ACCELERATOR ALIGNMENT

ALS Storage Ring Circumference Analysis

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Oct-11-2024

Outline

1. ALS Introduction
2. Method of Circumferences calculation
3. Uncertainty of circumference calculation
4. Circumference changes

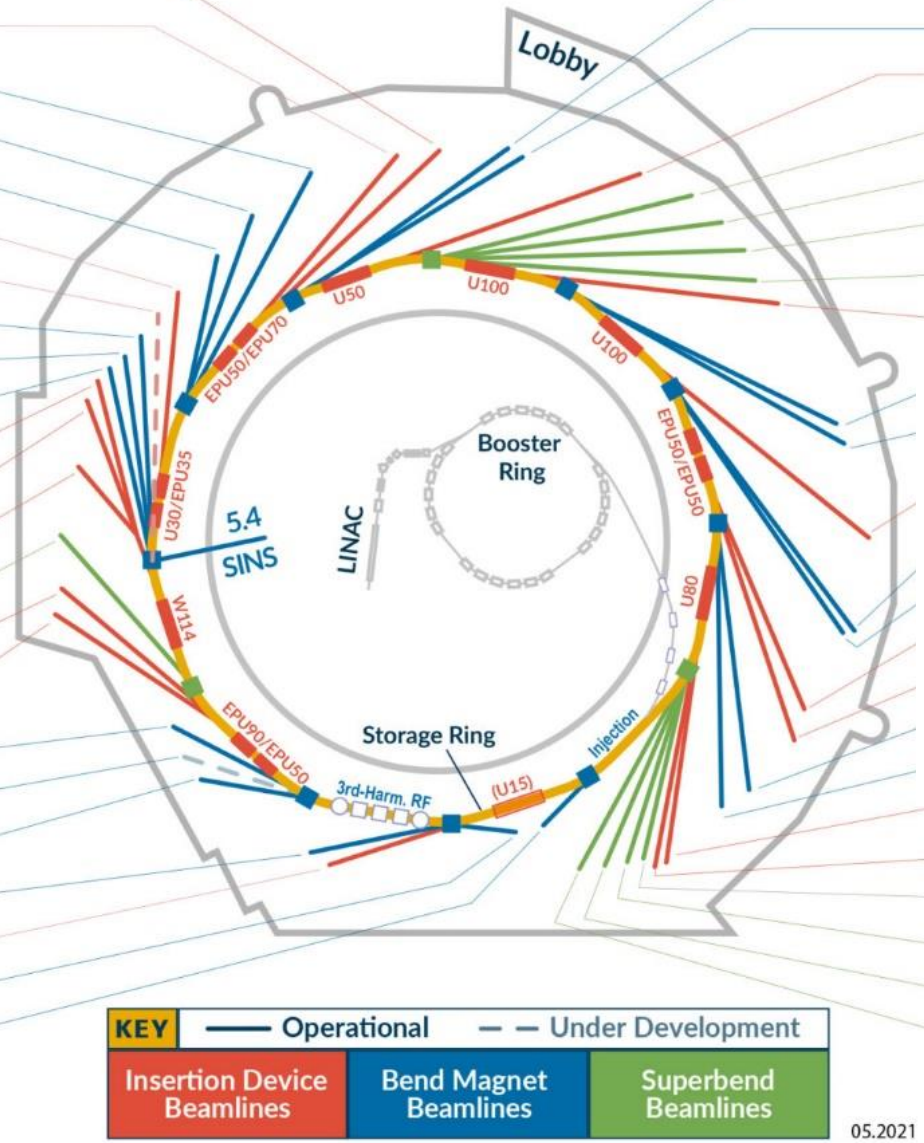
Cyclotron to Synchrotron

1940s

2020

Slide Credit: Cindy Lee

ALS Beamlines



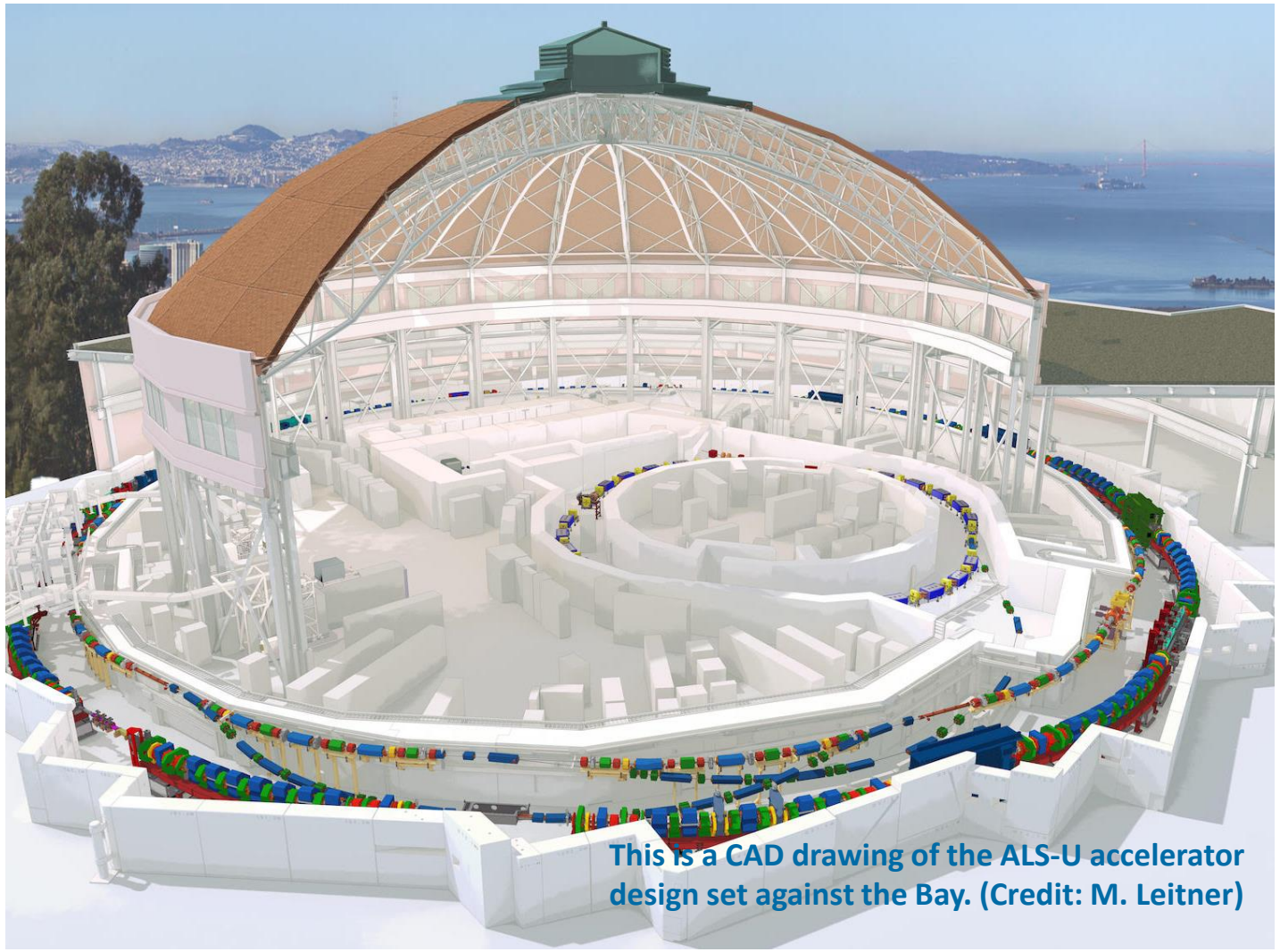
- Quantum Materials (MAESTRO) 7.0.2
- Coherent Scattering and Microscopy (COSMIC) 7.0.1
- Calibration, Optics Testing, Spectroscopy 6.3.2
- Magnetic Spectroscopy / Materials Science 6.3.1
- Full-Field Transmission Soft X-Ray Microscopy 6.1.2
- Energy, Catalytic, and Chemical Science (AMBER) 6.0.1
- Double-Dispersion RIXS (QERLIN) 6.0.2
- Polymer STXM 5.3.2.2
- STXM 5.3.2.1
- Research and Development (X-Ray Footprinting) 5.3.1
- Macromolecular Crystallography (BCSB) 5.0.3
- Macromolecular Crystallography (BCSB) 5.0.2
- Macromolecular Crystallography (BCSB) 5.0.1
- Macromolecular Crystallography (MBC) 4.2.2
- High-Resolution Spectroscopy (MERLIN) 4.0.3
- Magnetic Spectroscopy and Scattering 4.0.2
- General X-Ray Testing Station 3.3.2
- X-Ray Footprinting 3.3.1
- LIGA 3.2.1
- National Center for X-Ray Tomography 2.1
- Macromolecular Crystallography (GEMINI) 2.0.1
- Infrared Nanospectroscopy and Imaging 2.4
- IR Spectromicroscopy 1.4

- 7.3.1 High-Pressure In Situ Soft X-Ray Spectroscopy
- 7.3.3 SAXS/WAXS/GISAXS
- 8.0.1 Surface and Materials Science (RIXS)
- 8.2.1 Macromolecular Crystallography (BCSB/HHMI)
- 8.2.2 Macromolecular Crystallography (BCSB/HHMI)
- 8.3.1 Macromolecular Crystallography (TomAlberTron)
- 8.3.2 Tomography (micro-CT)
- 9.0 Chemical Transformations

- Infrared
- X-ray
- Ultraviolet

- 12.0.1 EUV Lithography Nanopatterning (MET/METS)
- 12.0.2 Coherent X-Ray Scattering
- 12.2.1 Small-Molecule Crystallography
- 12.2.2 Diffraction Under Non-Ambient Conditions
- 12.3.1 SIBYLS—MX and SAXS
- 12.3.2 Microdiffraction

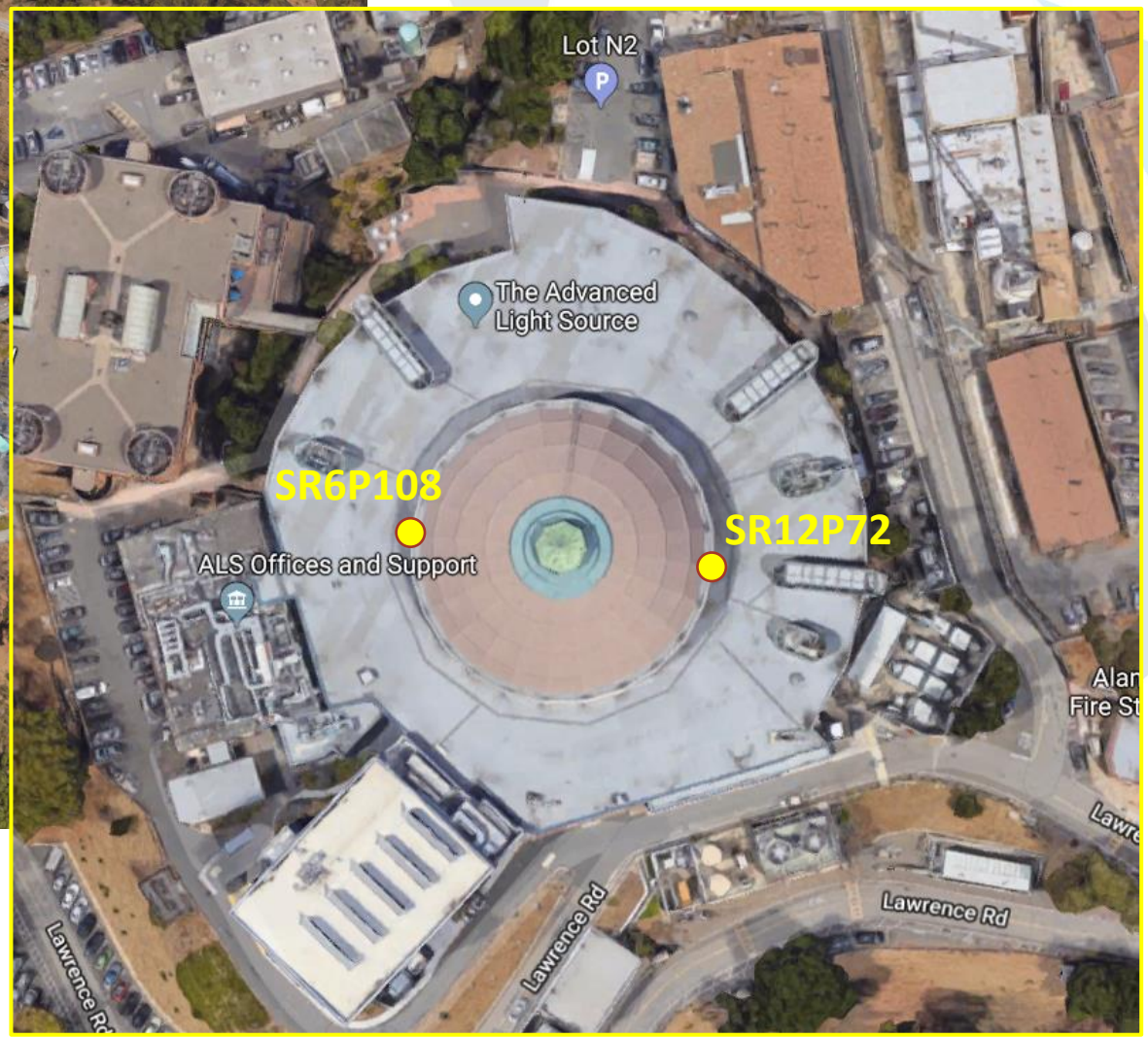
ALS Upgrade Project



This is a CAD drawing of the ALS-U accelerator design set against the Bay. (Credit: M. Leitner)

- Future (Accumulator Ring)AR will be hung on the inner wall.
- To understand how the ALS SR and Inner wall circumference change and predict the influence on ALS-U.
- With historical data, the circumference analysis is conducted.

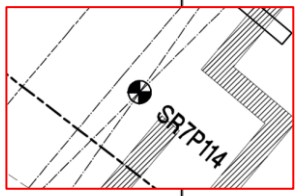
ALS Surroundings

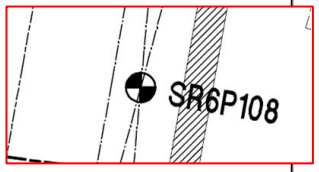


ALS Monument

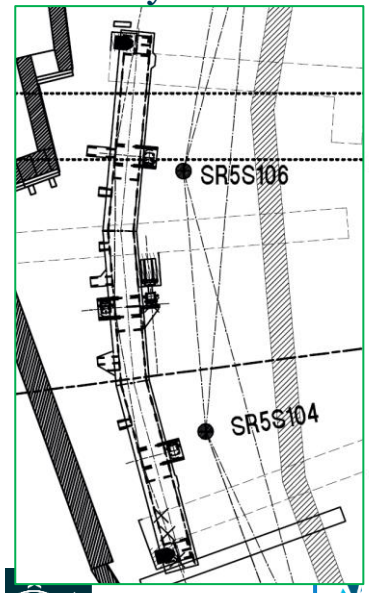
Area		Primary monuments	Secondary Monuments
Linac	LN	0	8
Linac to Booster	LTB	2	4
Booster Ring	BR	4	12
Booster to Storage Ring Transport	BTS	0	5
Storage Ring	SR	12	24

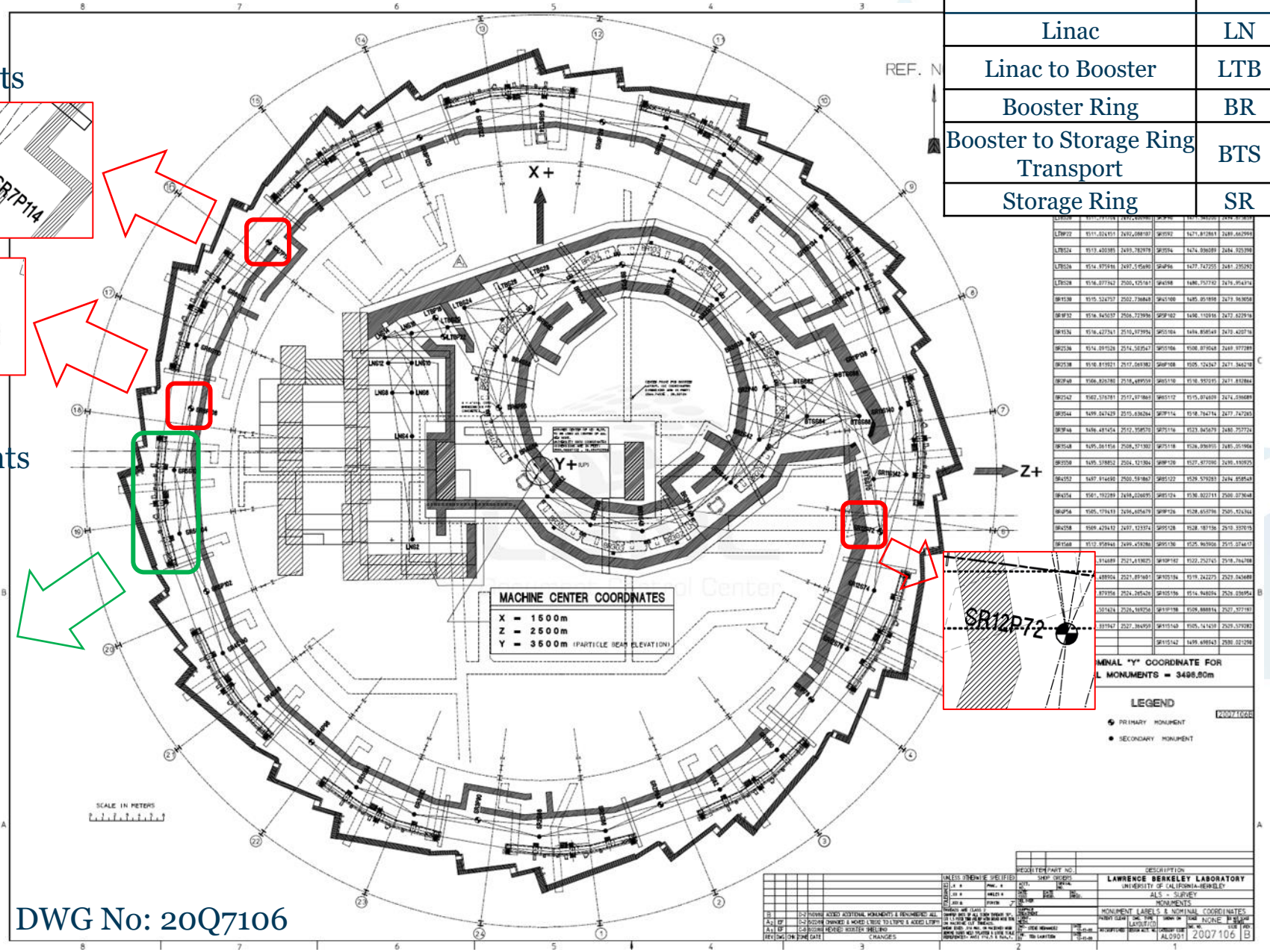
Primary Monuments





Secondary Monuments





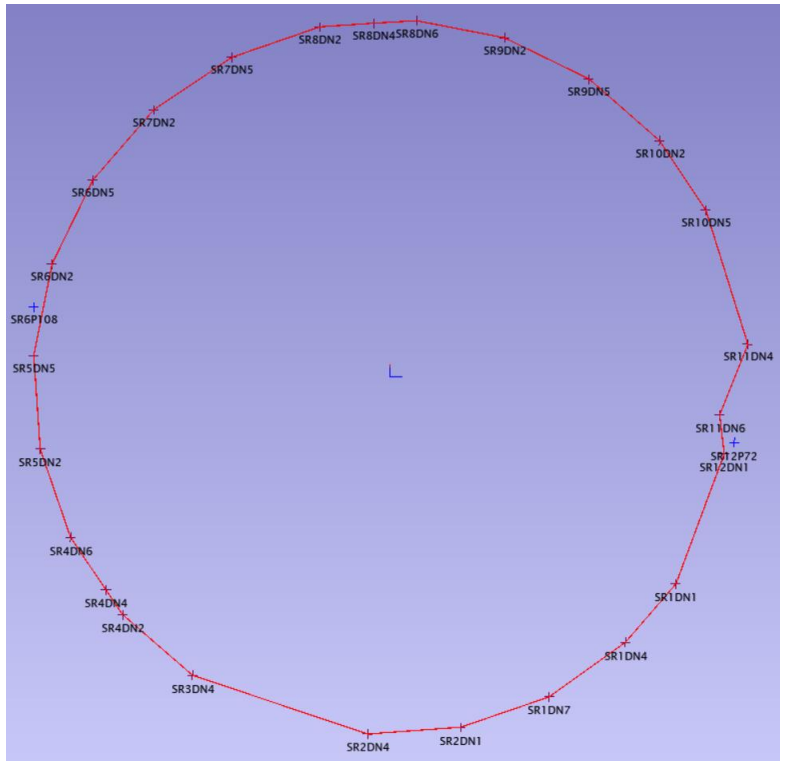
DWG No: 20Q7106

Primary monuments form a bone structure to connect each subsystems;
Secondary monuments are densified network for subsystems.

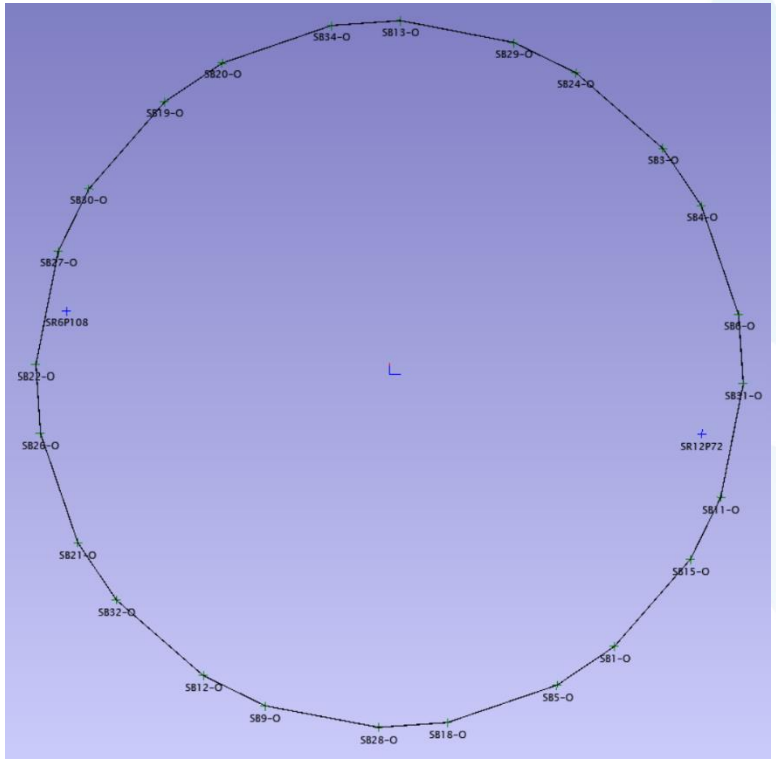
ALS Monument

Sector 1 Arc wall monuments

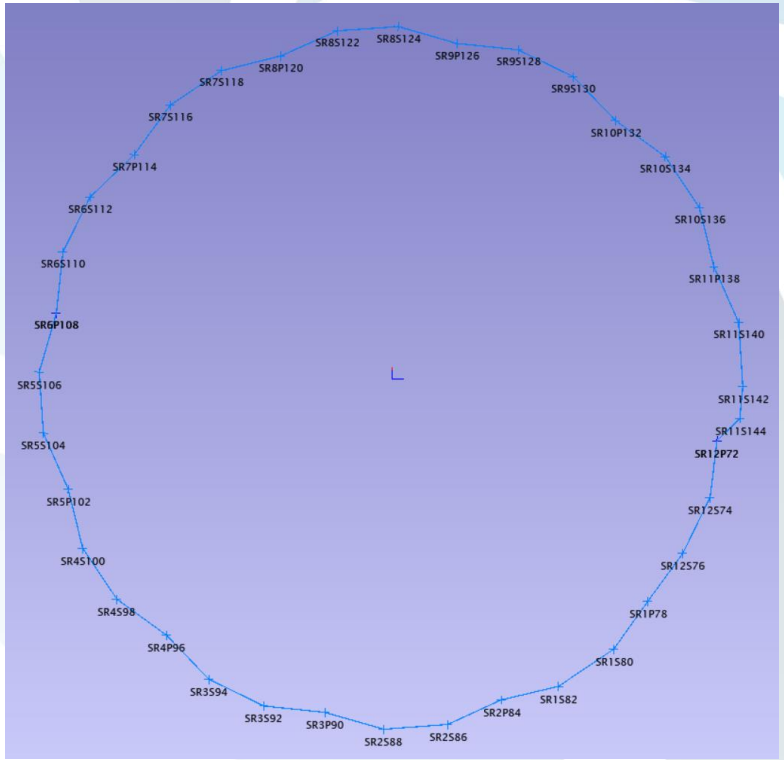
Method of Circumferences calculation



Inner Wall Monuments - Upper



Bend Magnet

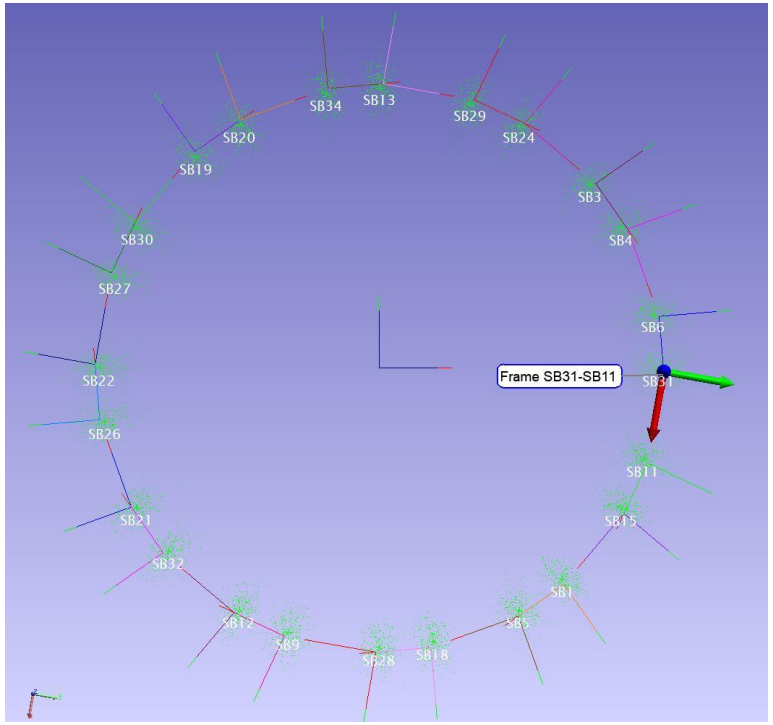


Floor Monuments

Calculate the distance between two adjacent monuments or magnets, add up to get the circumference.

1. Inner Wall Monuments – Upper: 25 Points.
2. Inner Wall Monuments – Lower: 45 Points.
3. Bend Magnet: Magnet center, Only the first and third bend magnet in each sector are used, 24 Points.
4. Floor Monuments: 37 Points.

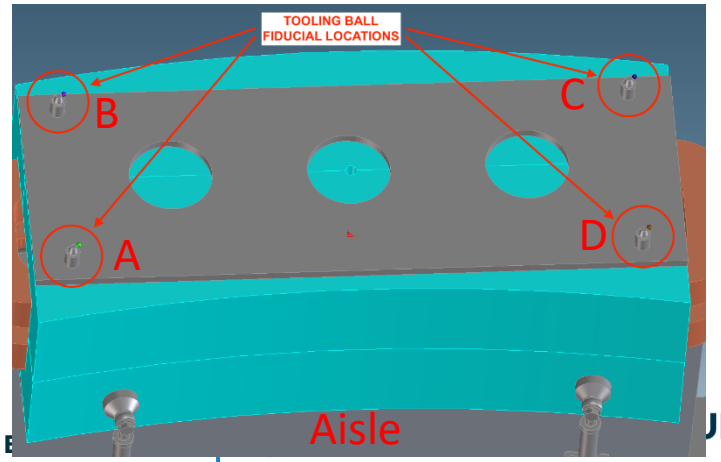
Uncertainty of circumference calculation



1. Every fiducial and monument is measured from more than one station, based on the instrument uncertainty and distribution of these measurements, Spatial Analyzer can calculate the uncertainty of each measured points.
2. Only the uncertainty along vectors between adjacent points will contribute to the total uncertainty of circumference calculation. Local frame on each vector is constructed to calculate this uncertainty U_i.
3. The uncertainty of total circumference:

$$U_{Cir} = \sqrt{U_0^2 + U_1^2 + \cdots + U_n^2} = \sqrt{\sum_{i=0}^{n} U_i^2}$$

4. Bend magnet center is hidden point, the uncertainty can not be calculated directly in the software. So the uncertainty of fiducial Cs are used to calculate the uncertainty of bend magnet circumference.



	Uncertainty/2σ (mm)
Floor	0.448
Inner Wall Upper	0.458
Inner wall Lower	0.586
Bends-C	0.430

Circumference change - WRT Last measurement

Circumference (Meter)										
Survey Date	Sep-2009	Oct-2010	Jun-2011	Jul-2011	Jan-2012	Apr-2014	May-2014	Jul-2018	Apr-2019	Jul-2019
Floor	188.404102	188.403805	188.403511	188.402866	188.402388	188.403431	188.402976	188.403479	188.402075	188.402119
Inner Wall Lower	180.037434	180.036890	180.036560	180.036293	180.035656	180.036367	180.036026	180.036682	180.035407	180.035666
Inner Wall Upper	179.868603	179.868083	179.867663	179.867374	179.866862	179.867433	179.867115	179.868204	179.866846	179.867240
SR Bends	196.583554	196.583005	196.582598	196.581368	196.581097	196.581773	196.581019	196.580471	196.579036	196.579176

Change WRT Last measurement (Millimeter)										
Survey Date		Oct-2010	Jun-2011	Jul-2011	Jan-2012	Apr-2014	May-2014	Jul-2018	Apr-2019	Jul-2019
Floor		-0.297	-0.294	-0.645	-0.478	1.043	-0.455	0.503	-1.404	0.044
Inner Wall Lower		-0.544	-0.330	-0.267	-0.637	0.711	-0.341	0.656	-1.275	0.259
Inner Wall Upper		-0.520	-0.420	-0.289	-0.512	0.571	-0.318	1.089	-1.358	0.394
SR Bends		-0.549	-0.407	-1.230	-0.271	0.676	-0.754	-0.548	-1.435	0.140

Note: Red means Ring Readjustment

1. 9 sets of survey data from Sep-2009 to July-2019.
2. The ring was readjusted in 2011 and 2014, so there are two sets of data from 2011 and 2014.
3. From 2014-May to 2018-July, no survey data.

Circumference change - WRT Last measurement

Change WRT Last measurement (Millimeter)										
Survey Date		Oct-2010	Jun-2011	Jul-2011	Jan-2012	Apr-2014	May-2014	Jul-2018	Apr-2019	Jul-2019
Floor		-0.297	-0.294	-0.645	-0.478	1.043	-0.455	0.503	-1.404	0.044
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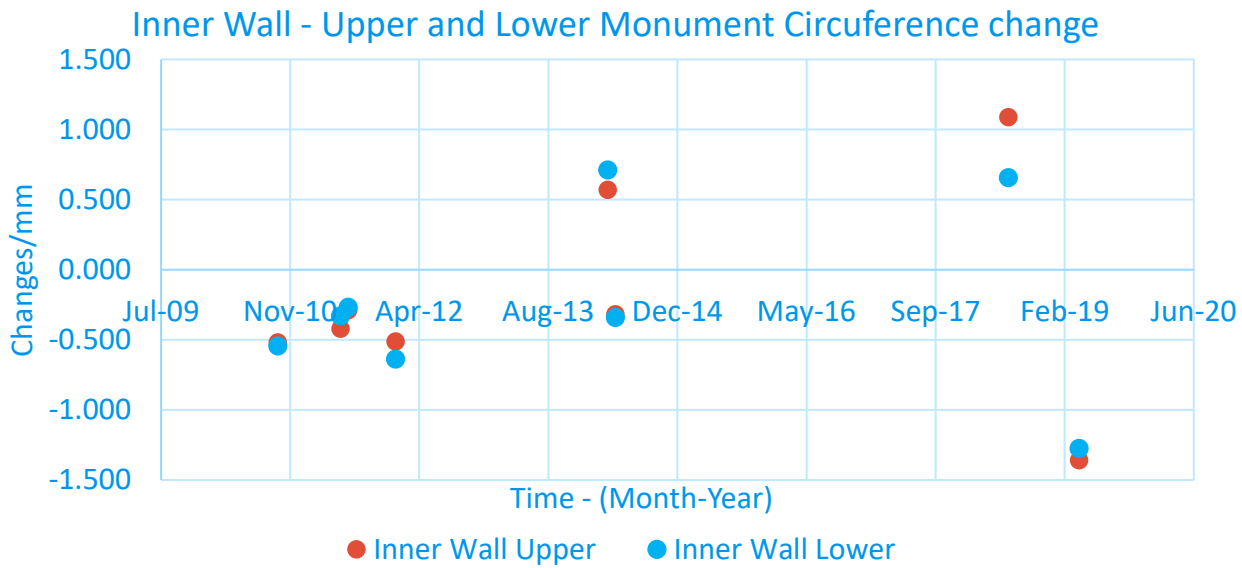
Inner Wall Upper		-0.520	-0.420	-0.289	-0.512	0.571	-0.318	1.089	-1.358	0.394
SR Bends		-0.549	-0.407	-1.230	-0.271	0.676	-0.754	-0.548	-1.435	0.140

Note: Red means Magnets were readjusted

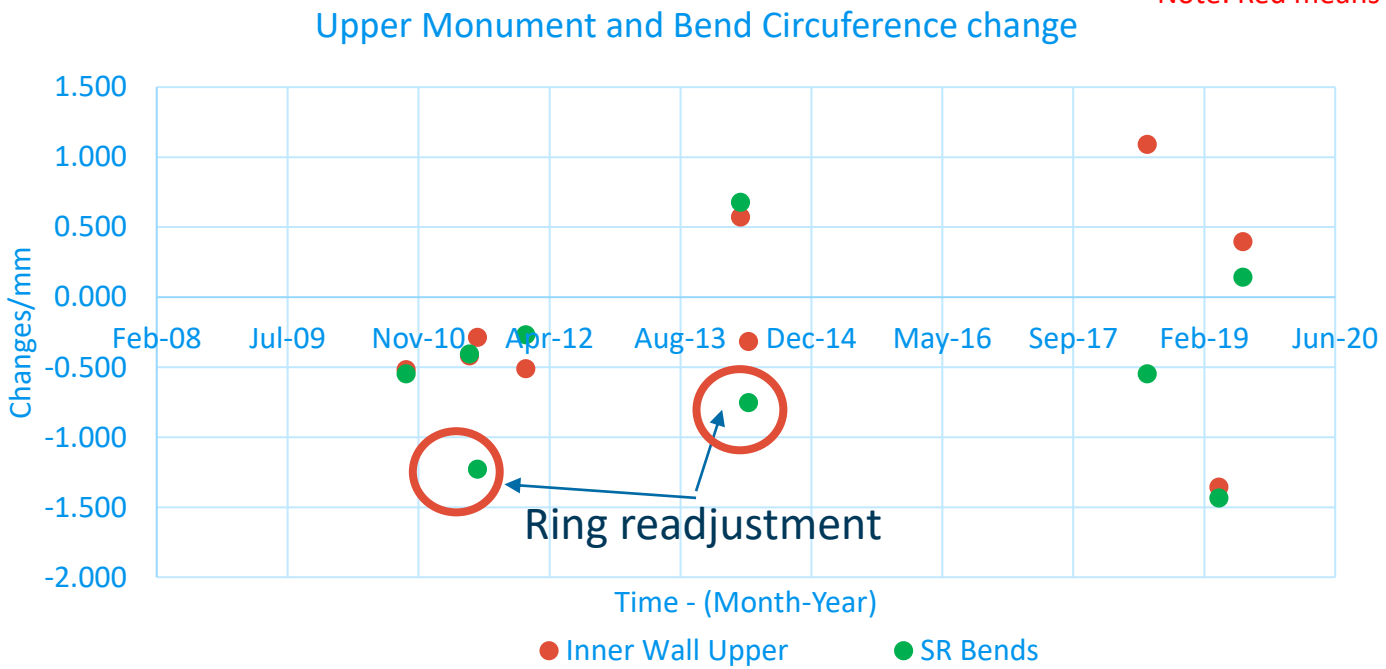


4. When the time frame is shorter than 2 years, circumference changes difference between the Inner wall Upper and lower Monument are smaller than 0.14mm, the RMS is 0.08mm. No Obvious inclination observed.
5. It's not predictable when the time frame is longer than 2year.

Circumference change - WRT Last measurement

Change WRT Last measurement (Millimeter)										
Survey Date		Oct-2010	Jun-2011	Jul-2011	Jan-2012	Apr-2014	May-2014	Jul-2018	Apr-2019	Jul-2019
Floor		-0.297	-0.294	-0.645	-0.478	1.043	-0.455	0.503	-1.404	0.044
Inner Wall Lower		-0.544	-0.330	-0.267	-0.637	0.711	-0.341	0.656	-1.275	0.259
Inner Wall Upper		-0.520	-0.420	-0.289	-0.512	0.571	-0.318	1.089	-1.358	0.394
SR Bends		-0.549	-0.407	-1.230	-0.271	0.676	-0.754	-0.548	-1.435	0.140

Note: Red means Magnets were readjusted

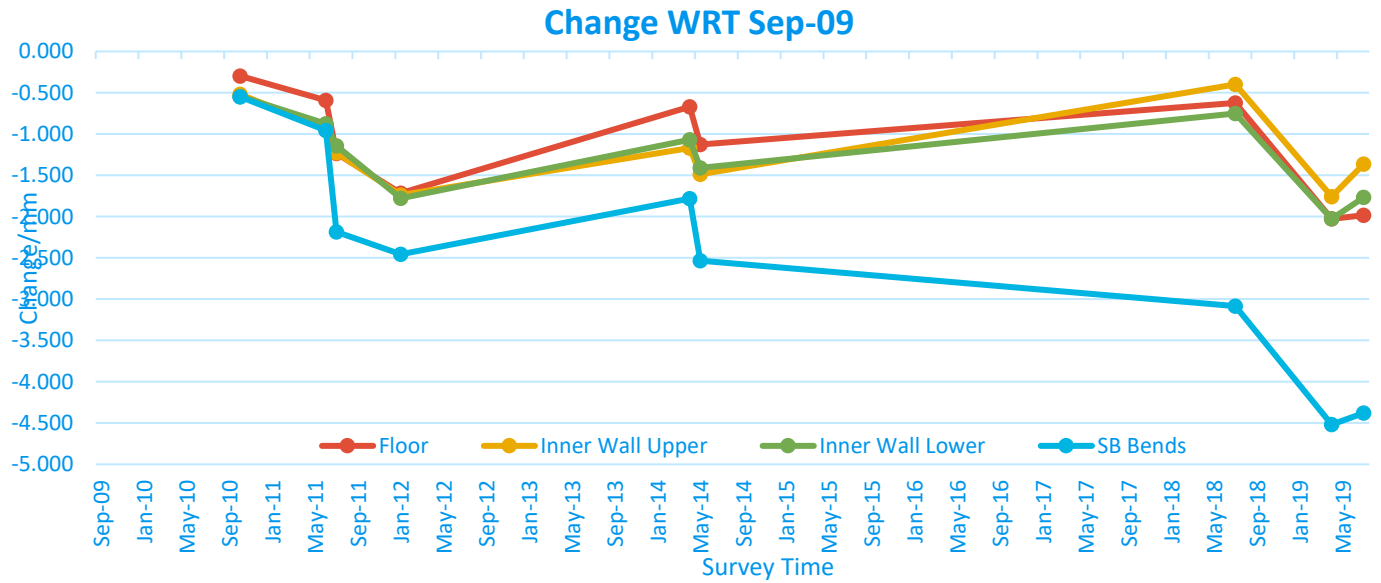


6. With the exception of Jul-2018 and the two Ring adjustments, the circumference changes difference between the Inner wall Upper Monument and Bends are smaller than 0.366mm, the RMS is 0.182mm.

Circumference change - WRT 2009-Sep

Change WRT Sep-09 (millimeter)										
Survey Date	Sep-2009	Oct-2010	Jun-2011	Jul-2011	Jan-2012	Apr-2014	May-2014	Jul-2018	Apr-2019	Jul-2019
Floor	0	-0.297	-0.591	-1.236	-1.714	-0.671	-1.126	-0.623	-2.027	-1.983
Inner Wall Lower	0	-0.544	-0.874	-1.141	-1.778	-1.067	-1.408	-0.752	-2.027	-1.768
Inner Wall Upper	0	-0.520	-0.940	-1.229	-1.741	-1.170	-1.488	-0.399	-1.757	-1.363
SR Bends	0	-0.549	-0.956	-2.186	-2.457	-1.781	-2.535	-3.083	-4.518	-4.378

Note: Red means Magnets were readjusted



7. The accumulative changes of the Wall upper and lower monuments circumference are smaller than 0.4mm with RMS 0.19mm, showing possible 2urad inclination changes over 10 years.

Relation between Rainfall and Circumference change

Circumference (Meter)									
Survey Date	2009-Sep	2010-Oct	2011-June	2011-Jul	2012-Jan	2014-Apr	2014-May	2018-Jul	2019-Apr
Floor	188.404102	188.403805	188.403511	188.402866	188.402388	188.403431	188.402976	188.403479	188.402075
Inner Wall Lower	180.037434	180.036890	180.036560	180.036293	180.035656	180.036367	180.036026	180.036682	180.035407
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SR Bends	196.583554	196.583005	196.582598	196.581368	196.581097	196.581773	196.581019	196.580471	196.579036
Change WRT Last measurement (Millimeter)									
Floor		**-0.297**	-0.294	-0.645	-0.478	1.043	-0.455	0.503	-1.404
Inner Wall Lower		**-0.544**	-0.330	-0.267	-0.637	0.711	-0.341	0.656	-1.275
Inner Wall Upper		**-0.520**	-0.420	-0.289	-0.512	0.571	-0.318	1.089	-1.358
SR Bends		**-0.549**	-0.407	-1.230	-0.271	0.676	-0.754	-0.548	-1.435

Rainfall data From 2009-2018 of SFO

unit: inch

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
2009	0.9	7.92	2.76	0.24	0.8	0	0	0	0.28	3.11	0.45	2.77	**24.09**
2010	6.66	3.42	2.79	3.59	0.95	0.07	0	0.01	0.02	1.81	3.1	6.71	**28.87**
2011	1.55	4.94	7.02	0.56	1.13	2.02	0.08	0.03	0	1.38	1.74	0.14	**15.64**
2012	2.68	1.09	5.7	2.64	0.02	0.14	0.01	0.01	0	1.47	4.5	7.11	**16.61**
2013	0.49	0.85	0.97	1.01	0.04	0.15	0	0.04	0.39	0	1.26	0.39	**12.54**
2014	0.06	5.82	2.95	1.59	0.03	0.01	0.08	0.01	0.55	0.46	2.29	11.7	**18.19**
2015	0	1.47	0.12	1.3	0.09	0.12	0.09	0.02	0.09	0	1.43	5.18	**23.26**
2016	7.03	0.98	6.83	1.46	0.15	0	0.02	0.02	0	2.43	2.21	4.39	**32.34**
2017	9.42	7.6	3.9	2.25	0	0.1	0	0.01	0.1	0.31	2.83	0.15	**17.53**
2018	5.21	0.42	4.54	3.91	0.04	0.01	0	0	0	0.21			

Data From: https://ggweather.com/sf/monthly.html

Relation between Rainfall and Cir change

From	To	Relative Rainfall		Cir Change/Floor
2009-Sep	2010-Oct	Dry	Wet	-0.297
2010-Oct	2011-Jun	Dry	Wet	-0.294
2011-Jun	2011-Jul	Wet	Dry	-0.645
2011-Jul	2012-Jan	Dry	Wet	-0.478
2012-Jan	2014-Apr	Dry	Wet	1.043
2014-Apr	2014-May	Wet	Dry	-0.455
2014-May	2018-July	Wet	Dry	0.503
2018-Jul	2019-Apr	Dry	Wet	-1.404

- 5 Sets of data show the circumference in wet season is shorter than dry season. The rest 3 sets of data show the opposite.
- With limited survey data, it's difficult to make correlation between circumference changes and seasons.

Summary

- With historical data, there are no wall inclination observed.
- The circumference changes difference between the Inner wall Upper Monument and Bends are smaller than 0.366mm, the RMS is 0.182mm. This is within the adjust range of RF system.
- From limited survey data and measurement uncertainty, it’s difficult to make correlation between circumference changes and seasons.

What has been presented is very much a Group Effort…

On behalf of the Survey and Alignment Group:

- **Federico Carrara**
- **Dan Ellis**
- **Chris Hernikl**

Thanks for your attention!