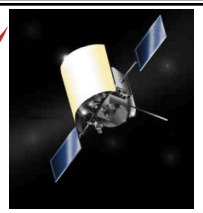

MESSENGER

Propulsion Latch Valve Magnetics Measurements

4 June 2002

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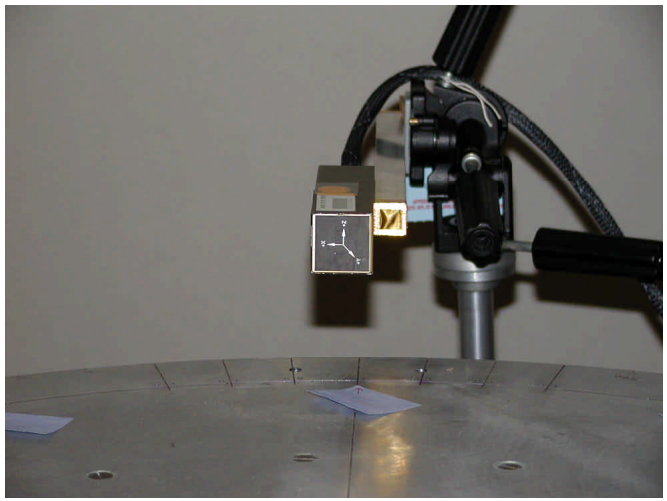
MESSENGER
Latch Valves: APL Facilities

Non-magnetic building

6’ Helmholtz coils

Control electronics: coils, test magnetometer, analysis computer



Non-magnetic turntable & miniature magnetometer

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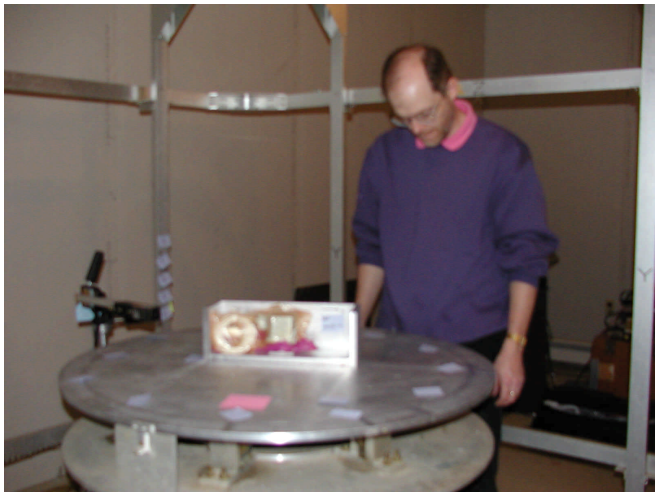
Latch Valves: Test Procedures 1

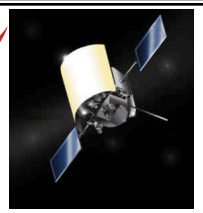
Installing a valve in test fixture



High-tech turntable rotation ‘system’

Near real-time analysis

Valves wrapped to stay clean w. mount exposed



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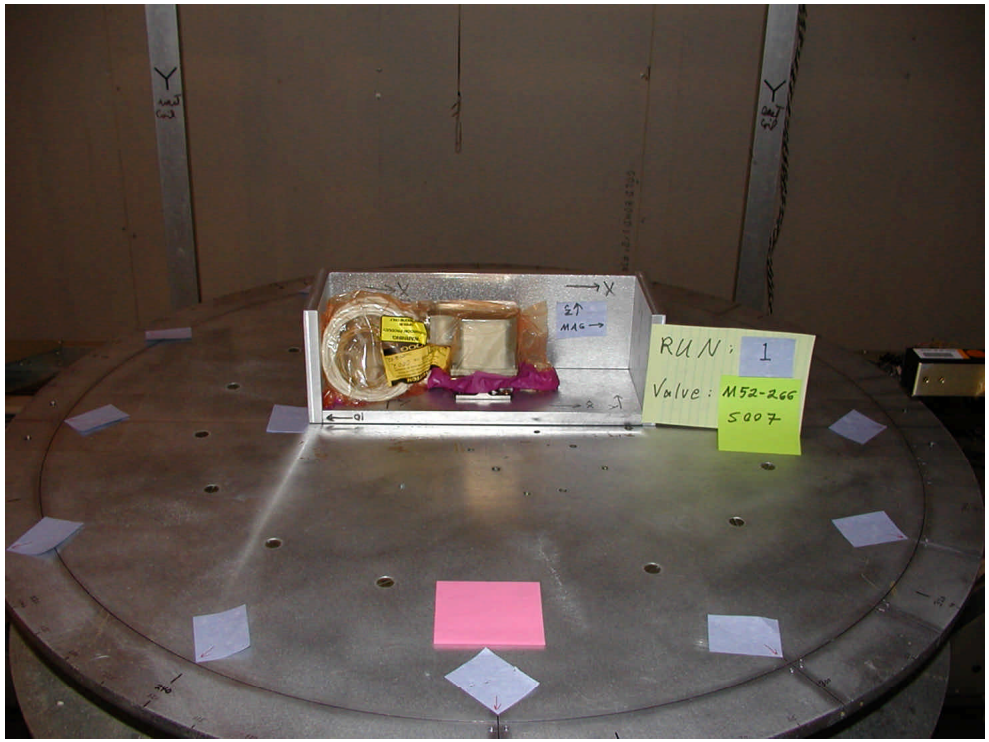
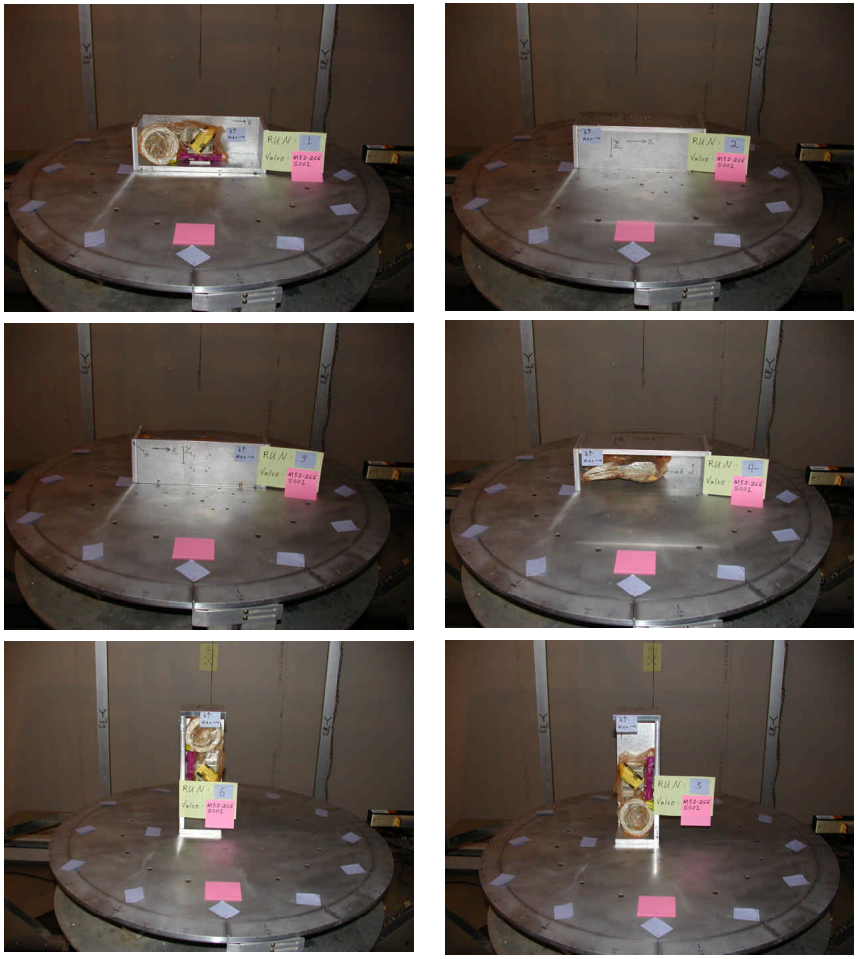
Latch Valves: Test Procedures 2

Orientation documented for every fixture placement.

Coordinate systems & their transformations:

- facility coords.
- fixture coords.





Test fixture used to provide accurate & safe positioning in all orientations.

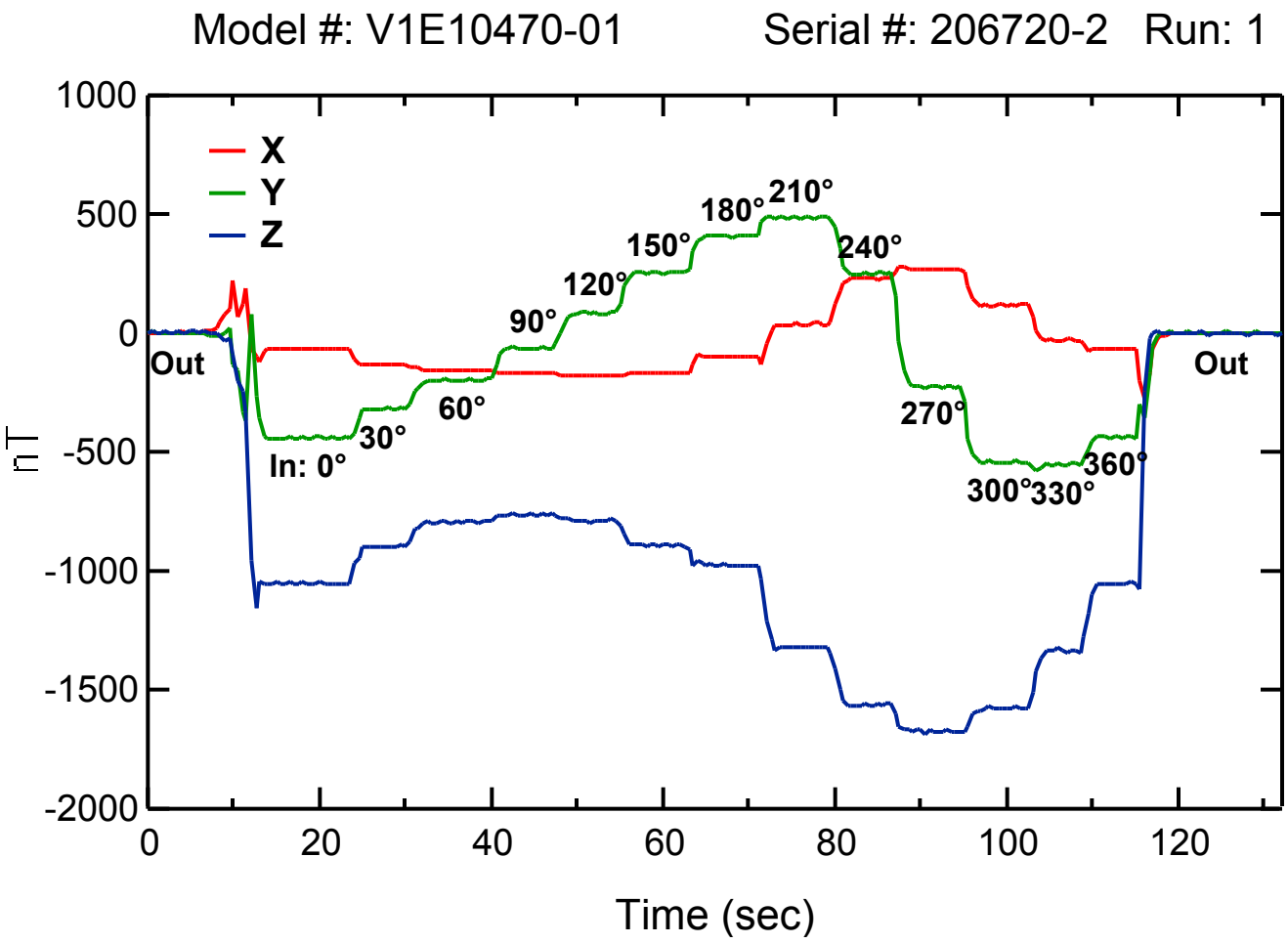
MESSENGER
Latch Valves: Results 1

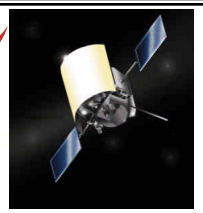
Six runs of 13 steps for every valve: 72 vector measurements covering ‘sphere’ around valve.

Average at each step vs table rotation angle: ‘zero’ taken as average of ‘Out’ values.

Helmoltz coils used to reduce background Earth’s field at valve to <1%

Residual facility and instrument noise: ~5 nT.





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Latch Valves: Results 2

A little math:

$\mathbf{r}_{p,j}$ = Location of jth fluxgate ring core. (Not all axes of ring core on same center.)
$\underline{\mathbf{T}}$ = Transformation matrix to facility coords (different for each fixture orientation)
$\underline{\mathbf{R}}(\theta)$= Table rotation.
$\mathbf{r}_{\mu}$ = Position of the moment. Allow unknown offset. In facility coords: $\mathbf{r}_p^* = \underline{\mathbf{R}}(\theta)\cdot\underline{\mathbf{T}}\cdot\mathbf{r}_p$
$\boldsymbol{\mu}$ = Magnetic moment. In facility coords: $\boldsymbol{\mu}^* = \underline{\mathbf{R}}(\theta)\cdot\underline{\mathbf{T}}\cdot\boldsymbol{\mu}$

$$\mathbf{B}_j = \left(3(\mathbf{r}_{p,j} - \mathbf{r}_{\mu}^*) \left[(\mathbf{r}_{p,j} - \mathbf{r}_{\mu}^*)\cdot\boldsymbol{\mu}^*\right] - (\mathbf{r}_{p,j} - \mathbf{r}_{\mu}^*)^2\, \boldsymbol{\mu}^* \right) / \left(\left| \mathbf{r}_{p,j} - \mathbf{r}_{\mu}^* \right|^5 \right)$$

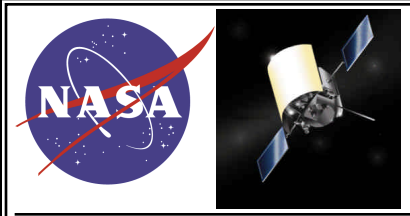
([**B**]=nT, [**r**]=meters, [$\boldsymbol{\mu}$]=nT-m^3)

Let $\underline{\mathbf{A}}_j = \{1/(| \mathbf{r}_{p,j} - \mathbf{r}_{\mu}^*|^5) \}(3(\mathbf{r}_{p,j} - \mathbf{r}_{\mu}^*)(\mathbf{r}_{p,j} - \mathbf{r}_{\mu}^*) - (\mathbf{r}_{p,j} - \mathbf{r}_{\mu}^*)^2\, \underline{\mathbf{I}})\cdot\underline{\mathbf{R}}(\theta)\cdot\underline{\mathbf{T}}$

Then $\mathbf{B}_j = \underline{\mathbf{A}}_j\cdot\boldsymbol{\mu}$

216 element vector, $\mathcal{B}$, all of the magnetic field readings for a given valve.
216 row 3 column operator, $\underline{\mathcal{A}}$, constructed so that $\mathcal{B} = \underline{\mathcal{A}}\cdot\boldsymbol{\mu}$ which is solved to get $\boldsymbol{\mu}_{fit}$.
Residual $\delta\mathcal{B} = \mathcal{B} - \underline{\mathcal{A}}\cdot\boldsymbol{\mu}_{fit}$ measures the error in normalized form $\Delta = \sqrt{(\delta\mathcal{B}\cdot\delta\mathcal{B}/\mathcal{B}\cdot\mathcal{B})}$

The position of the moment found by minimizing Δ with respect to $\mathbf{r}_p$.



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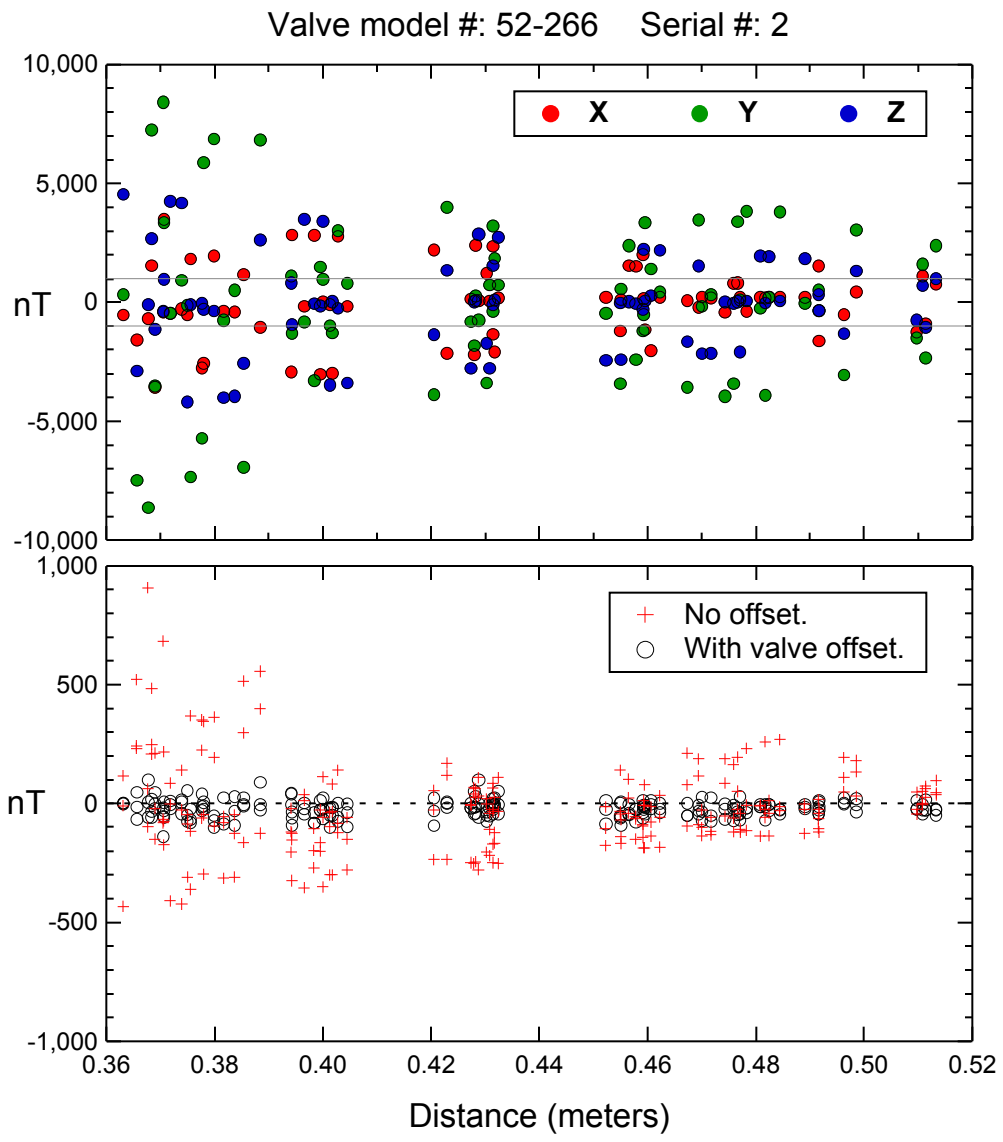
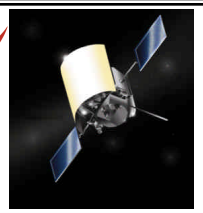
Latch Valves: Results 3

- Field of ~8,000 nT at 38cm gives a moment of ~220 nT-m^3.
- Residuals without offset are ~8%. With offset residuals decrease to ~1.5%.
- Location of valve moment determined to ~ 1mm.
- Vector moment determined to ~3 nT-m^3.





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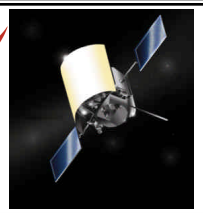
Latch Valves: Results 4

Model Number	Serial Number	M_X	M_Y [nT m^3]	M_Z	Residual [%]	dX	dY [cm]	dZ
52-266	1	-59.7	3.7	309.7	1.34	0.04	-0.17	-1.17
52-266	2	-30.3	4.1	217.3	1.50	-0.04	-0.10	-1.16
52-266	3	-38.4	7.3	205.7	1.56	-0.08	-0.14	-1.15
52-266	4	-45.1	9.4	271.9	1.43	-0.11	-0.17	-1.18
52-266	5	-44.3	4.0	273.3	1.42	-0.09	-0.13	-1.19
52-266	6	-46.2	4.8	272.1	1.42	-0.10	-0.13	-1.21
52-266	7	-33.3	7.3	176.1	1.58	0.08	-0.16	-1.21
V27200-818-1	1	-6.6	0.0	0.1	23.03	-1.67	-0.05	-3.29
V27200-818-1	2	-6.4	-1.6	1.9	3.72	-1.60	-0.12	-3.35
V27200-818-1	3	-7.7	0.5	1.7	3.94	-1.73	0.02	-3.24
V1E10470-01	206720-1	19.7	1.2	81.2	4.91	0.26	-0.03	-1.07
V1E10470-01	206720-2	18.1	0.5	82.0	4.32	0.28	-0.07	-1.09
*V27200-818-1	1	50.0	-0.1	0.0	3.82	-0.11	0.03	-3.66
*V27200-818-1	2	43.7	-1.4	0.6	4.26	-0.15	0.05	-3.72
*V27200-818-1	3	43.9	0.0	-1.2	4.35	-0.03	0.04	-3.70



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Latch Valves: Results 5

- Results allow calculation of magnetic field to within 1 nT.
- Cancellation magnet design underway. Completion est. June 13.
- Delivery of to Aerojet and validation test last week of June (target).

Model Number	Serial Number	Moment [nT-m3]	ΔM 3-sigma [nT-m3]	ΔB at MAG [nT]
52-266	1	315.46	1.52	4.9
52-266	2	219.43	1.18	3.4
52-266	3	209.41	1.17	3.3
52-266	4	275.79	1.42	4.3
52-266	5	276.93	1.41	4.3
52-266	6	276.03	1.41	4.3
52-266	7	179.36	1.02	2.8
V27200-818-1	1	6.62	0.55	0.1
V27200-818-1	2	6.90	0.09	0.1
V27200-818-1	3	7.96	0.11	0.1
V1E10470-01	206720-1	83.59	1.48	1.3
V1E10470-01	206720-2	84.01	1.31	1.3
System:	(smallest μ)	1534.05	3.5 (81)	24.0