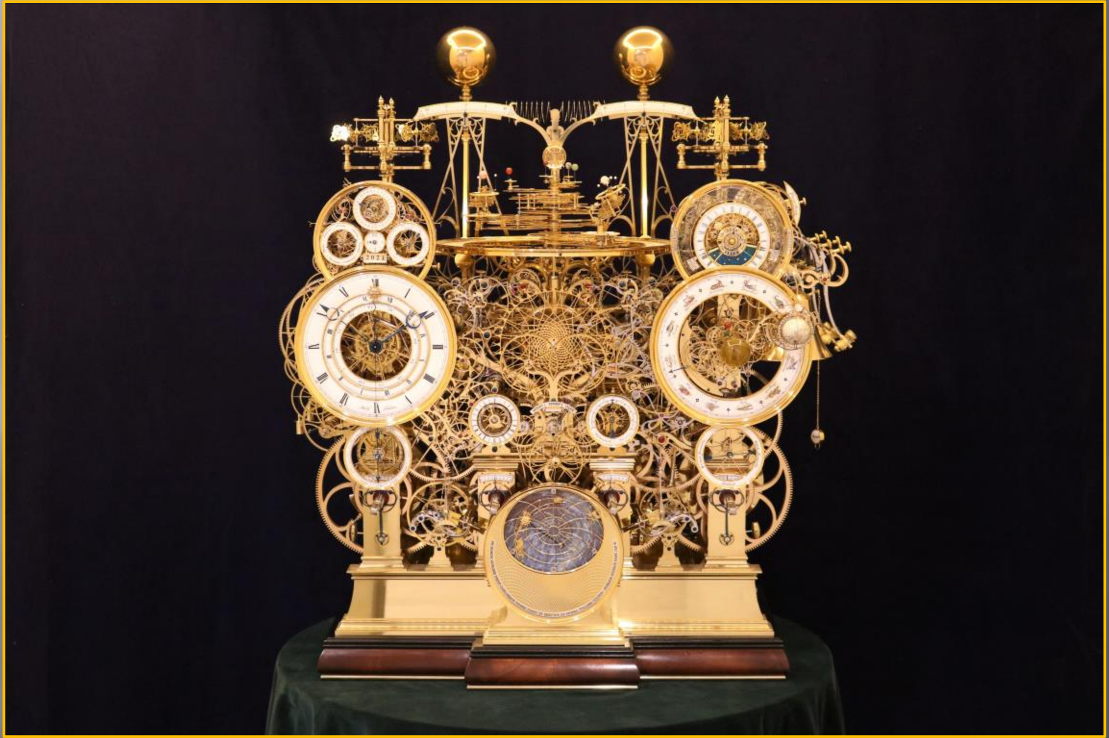
The Astro-skeleton clock completed

‘A Machine Engineered To Amaze’

By Mark Frank, Copyright February 2023



NATIONAL CONVENTION 80th
LANCASTER, PA • 2023
NAWCC

www.my-time-machines.net

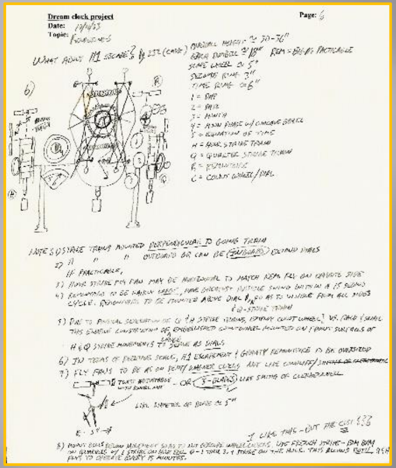
Introduction – philosophy guiding the design

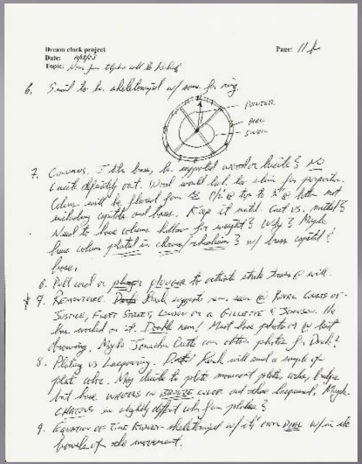
1. Physical presence / scale. Larger than a typical skeleton clock.
2. Complexity. Multiplicity of functions and components
3. Beauty
4. Movement.
   a. Multiple remontoire
   b. Compound flies, epicyclical tourbillon flies
   c. Escapement and pendulums with strong visual impact
   d. Frequent cycling at differing intervals
   e. Use of multiple, highly polished surfaces

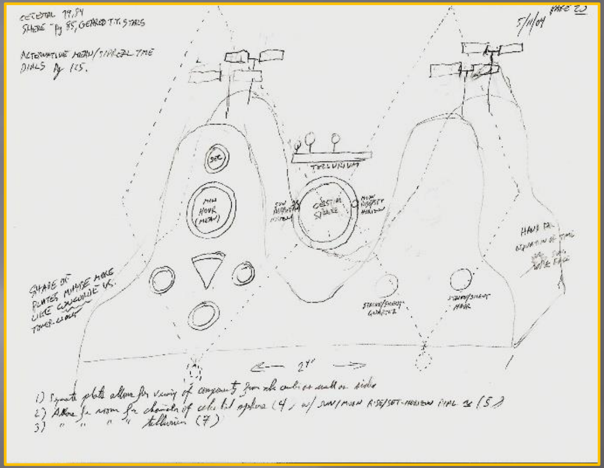
Additional features:

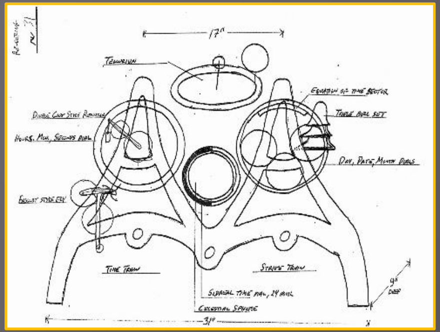
1. Whimsical design touches
   Classical architectural foundation supports an ivy and forest setting in which are allegorical animals. Above that forest is the firmament as represented by the orrery above
2. Minimum number of dials convey data; allowing for maximum view of the movement
3. Modular design to facilitate future servicing
4. The machine will be a dry runner eliminating almost oil, a major source of clock failures. It was Breguet who was purported to have said: "Give me the perfect oil and I will give you the perfect watch". Obviously no oil is the perfect solution.
5. Incredible attention to detail, finish; quality throughout

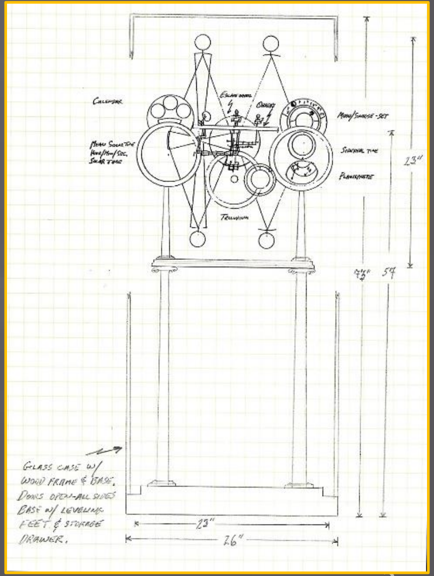
Some early design concept drawings, 2003-2005

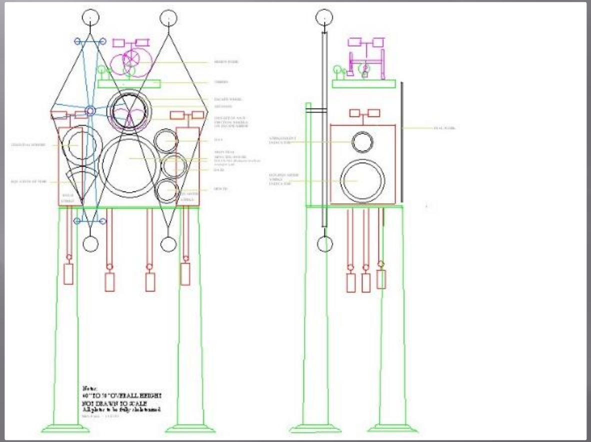


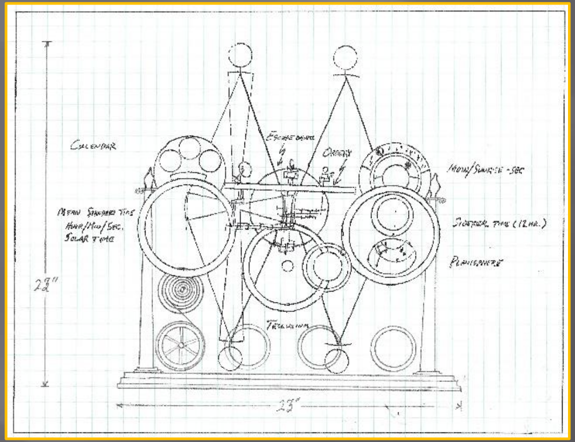




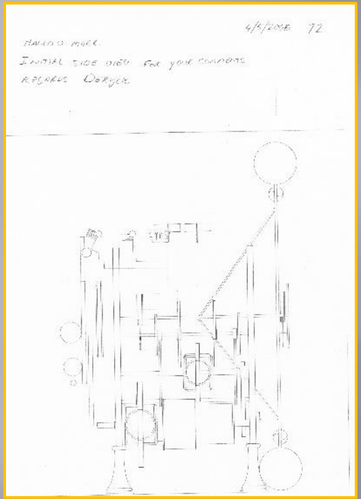


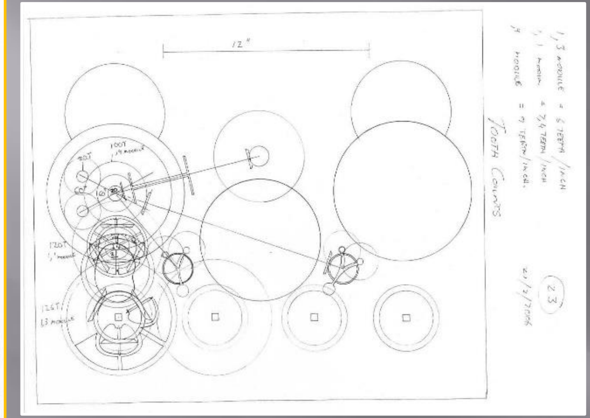


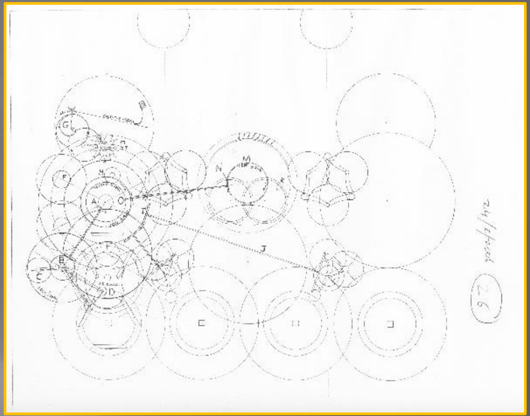


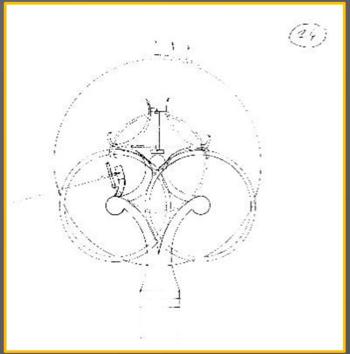


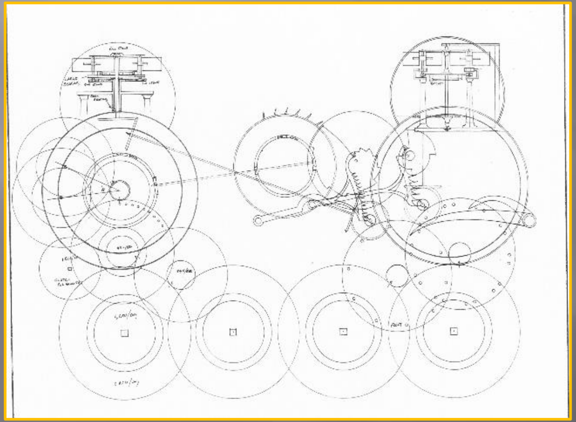
Buchanan early design drawings, 2006

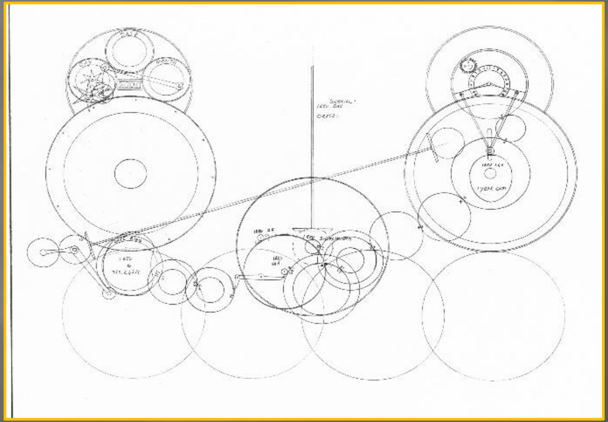




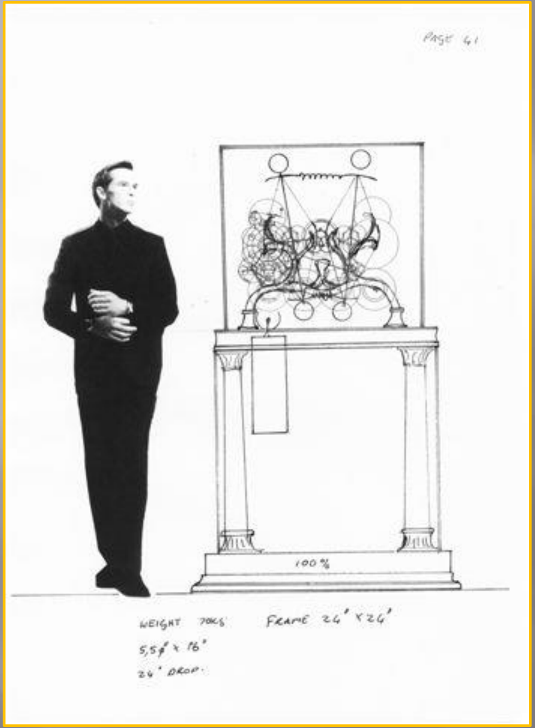


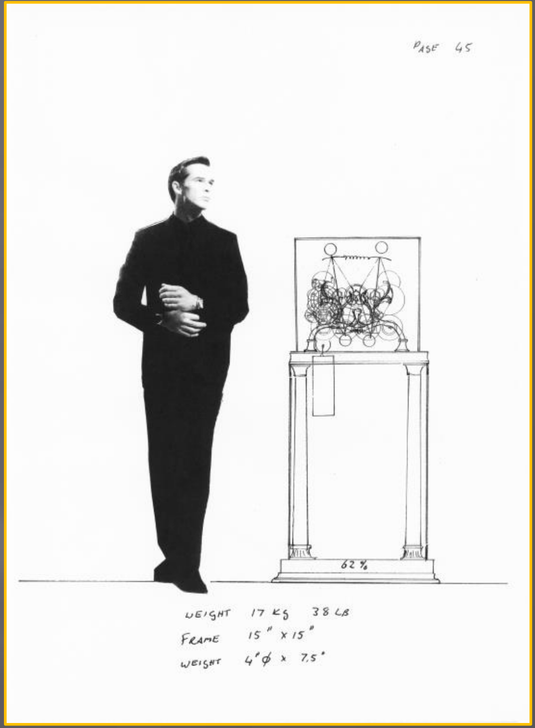






Buchanan design drawings, 2006





Here we contemplated what the overall size of what the machine should be. In reality we could never have chosen a smaller size since many of the ‘behind the dial work’ components reached the scale of pocket watch components – the limits of Buchanan’s tooling.

Screen shot from website, construction index

ASTRONOMICAL SKELETON CLOCK PROJECT, INDEX

Date	
	2003
	Pre-construction design work
10-12/03	My early concept designs page 1
	2004-2006
5/04 - 4/05	My early concept designs page 2
4/04, 1/06	Buchanan's early concept designs
	2006
	Creation of working component models and first generation mockup
3/06	Working mockups in plastic - going barrel and planisphere
4/06	Working mockups in plastic - escapement and remontoire
5/06	Fabricator's design drawings page 1
5/06	Fabricator's design drawings page 2
01-06/06	Fabrication of full scale mockup
7/06	Full scale mockup page 1
7/06	Full scale mockup page 2
7/06	Orrery detail
	2007
	Fabrication Begins
07-9/07	Main wheels, barrels & maintaining power systems
10-12/07	Wagner dual remontoire, wheels, differential drive (this drives the time train)
	2008
01/08	Wagner dual remontoire, output, cage, chaton assemblies
02/08	Planisphere design work
03/08	Going train
04/08	Bevel wheels, fly design, columns, screws
05/08	Wagner remontoire fly fabrication - rough out
06/08	Wagner remontoire fly fabrication - finish work
07/08	Assembly of fly to remontoire and going train
08/08	Main wheel clicks; begin the escapement antifriction wheel assembly
09/08	Escapement wheels and finish antifriction wheel assembly
10/08	Begin pendulum balance assemblies - arbors
11/08	Pendulum balance assemblies - antifriction wheels and their plates, complete arbors
11/08	Pendulum balance assemblies - begin balances
12/08	Pendulum balance assemblies - complete balances
	2009
01/09	Grasshopper escapement assemblies
02/09	Redesign of grasshopper escapement assemblies
03/09	Redesign of movement frame Fly fan decoration; time train clutch
04/09	Refine remontoire components. Seconds drive, begin celestial train
05/09	Equation of time assembly, begin Robin remontoire, fly fan decoration
06/09	Continue Robin remontoire. (this drives the celestial train)
07/09	Continue Robin remontoire
08/09	Continue Robin remontoire
09/09	Finish Robin remontoire. Begin lower movement frame
10/09	Complete lower movement frame; Bell strike hammer lift cams
11/09	Bells; work for Horological Journal cover, Jan. 2010
12/09	Begin upper movement frame Project to date video page
	2010
01/10	Upper frame, stop work and state-of-wind indicators
02/10	Cable hooks; Stop work; begin power reserve indicators
03/10	Redesigned barrel clicks; continue power reserve indicators
04/10	Finish power reserve indicators; prep work upper frames
05/10	Continue prepping upper frames, some finish & trim work
06/10	Rough upper frames complete, some finish & trim work
07/10	Time; central frames and pendulum support fabricated
08/10	Demonstration clutch parts, project to date photos; films
09/10	Balance diagonals; poising weights, strike train rear frame
10/10	Strike snail transfer train
11/10	Begin Fasoldt epicyclical strike train fly fans
12/10	Strike train fly fans, begin strike/ repeat control assemblies
	2011
01/11	Strike and repeat control assemblies, schematics; rack mockups
02/11	Strike and repeat control assemblies, main strike fly fan detents
03/11	Strike and repeat control assemblies, initiators
04/11	Strike and repeat control assemblies, complete initiators
05/11	Strike and repeat control assemblies, continue main strike fly detents
06/11	Strike and repeat control assemblies, rack pawls; rack let down flies
07/11	Strike and repeat control assemblies, quarter and hour racks Project to date photos and video page

Date	
	2012
8/11-9/12	Fourteen month hiatus for restoration of the Pouvillon clock
10/12	Movement stand, inner steel structure
	Seven month hiatus for manufacturing facility relocation
	2013
	Fabrication of enamel dial work, compilation Feb. 2008 - May 2013
	Dial work - Feb. 2008 to Jan. 2012, planisphere, main time dial
06/13	Dial work - Mar. 2012 - Aug. 2012, tellurian dial
	Dial work - Mar. 2012 - Aug. 2012, orrery, redo main time dial
	Dial work - Dec. 2012 - May 2013, redo orrery, complete remaining dials
07/13	Fabricate replacement of main frame pillars
08/13	Fabricate replacement of main frame pillars
09/13	Celestial train demonstration drive, the orrery dual speed transmission
10/13	Continue demonstration drive transmission, begin orrery output gearing
11/13	Finish celestial train demonstration drive and orrery output gearing
12/13	No work
	2014
01/14	Strike snails and begin strike hammer linkages
02/14	Continue strike hammer linkages
03/14	Finish strike hammer linkages
04/14	Bell hammers
05/14	No work
06/14	No work
07/14	Strike and repeat selection levers, misc. parts, complete strike control system
08/14	No work
09/14	Begin drives to sidereal, equation of time and calendar functions
10/14	Finish last month's work. Begin mockup for the perpetual calendar module
11/14	Sidereal, equation drives, kidney cam, equation of time system complete
12/14	Finish mockup for perpetual calendar remontoire, begin calendar fabrication
	2015
01/15	Begin the reversible, third-order perpetual calendar calculator complication module
02/15	Complete the calendar calculator module
03/15	Calendar remontoire and demonstration overdrive safety clutch
04/15	Calendar readout control levers, begin digital year indicator
05/15	Continue calendar readout control levers and digital year indicator
06/15	Skeletonize calendar frames, other misc. items
07/15	Finish perpetual calendar, Begin tellurion module, design & wheel blanks
08/15	Continue tellurion assembly, frame blanks, spoke wheels
09/15	Continue tellurion assembly, spoke and plant wheels
10/15	Continue tellurion assembly, skeletonize frames
11/15	Continue tellurion assembly, begin solar and lunar eclipse demo functions
12/15	No work
	2016
01/16	Continue tellurion assembly, sidereal, synodic month; solar, lunar horizons
02/16	Complete tellurion assembly, and sidereal dial drives
03/16	Pendulum spring regulator assemblies
04/16	Miscellaneous attachment parts for pendulum springs
05/16	Begin preparations for rating the clock, start final finishing of escapement
06-07/16	Continue final finishing of escapement, begin balance springs testing
08/16	Complete final finishing of escapement, begin balance springs testing
09/16	Continue balance springs testing, fabricate tellurion Earth globe
10/16	No work, My visit to the firm of Buchanan
11/16	Sun / Moon rise/ set module, dial design and development of first & second-order moon anomaly functions
12/16	No work.
	2017
01/17	Sun / Moon rise/ set, begin Great Anomaly & Projection variable differentials
02/17	Sun / Moon rise/ set, complete variable differentials
03/17	Fabricate the analog thermometer
04/17	Sun / Moon rise/ set, begin dial output drive assemblies
05/17	Sun / Moon rise/ set, dial output drive assemblies and differential frame
06/17	Sun / Moon rise/ set, dial output drive assemblies, module frames, shutter cam rollers, differential setting & dials
07/17	Sun / Moon rise/ set dial output drive assemblies, sun drive center sector dials
08/17	Sun / Moon rise/ set, sun hand, glass dial work, redo center dial and bezel
09/17	Sun / Moon rise/ set, finish sun hand, glass dial frame, shutter setting dial
10/17	Mechanically complete Sun/Moon rise/set; horizon shutter cams, movable dial plaques
11/17	Finishing work: Sun/Moon rise/ set assembly
12/17	No work.
	2018
01/18	Miscellaneous projects; preliminary mockup for planisphere module
02/18	Begin planisphere module
03/18	Continue planisphere module

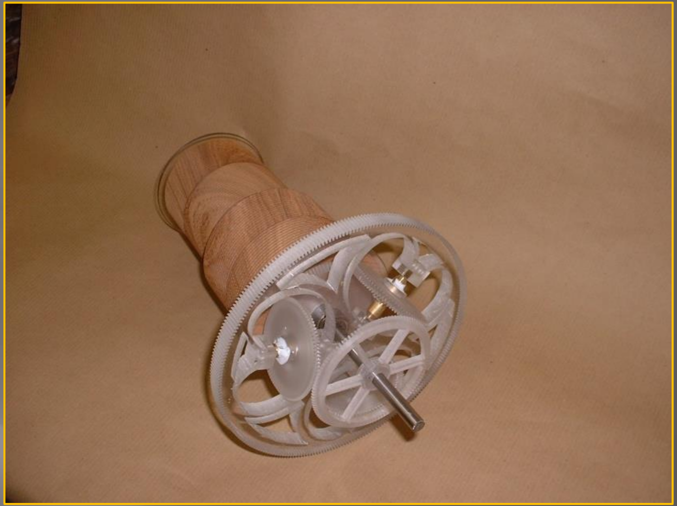
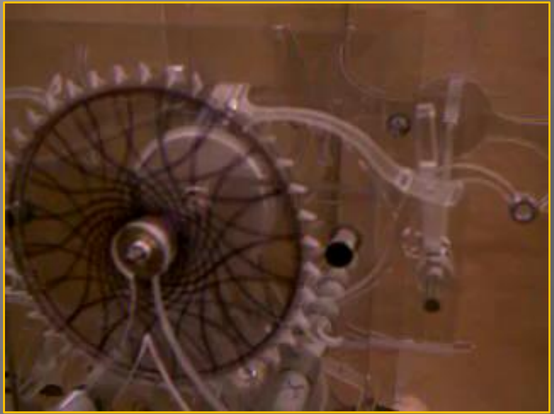
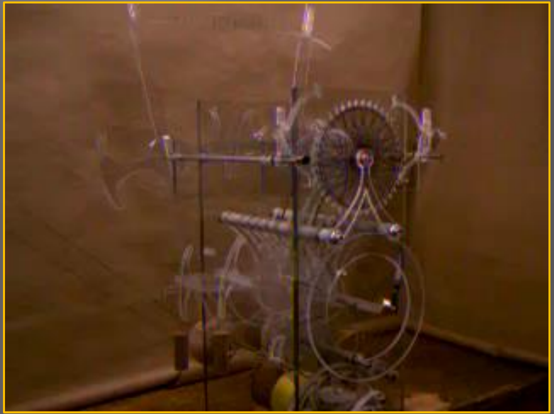
www.my-time-machines.net/astro_index.htm

The first generation wooden mockup – plate and spacer frame, 2006

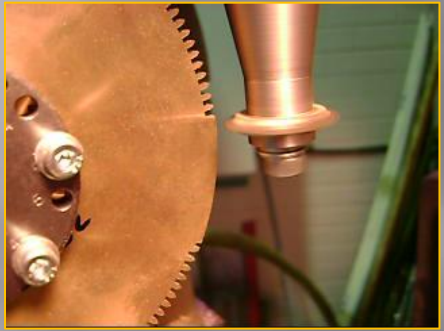
Andrew at 2 yrs old giving initial test drive in 2006
Below is the first style mockup completed in 2006

Testing the time train in functioning plastic models, April 2006



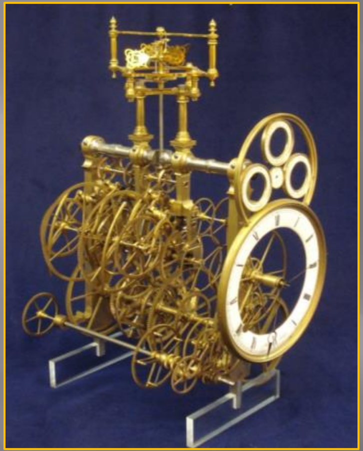
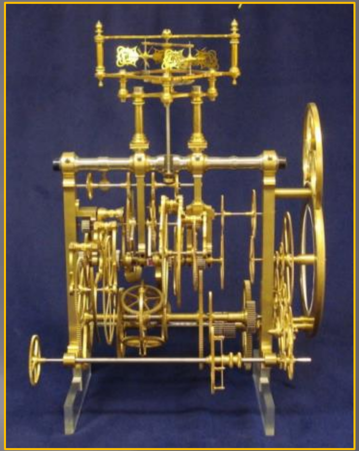
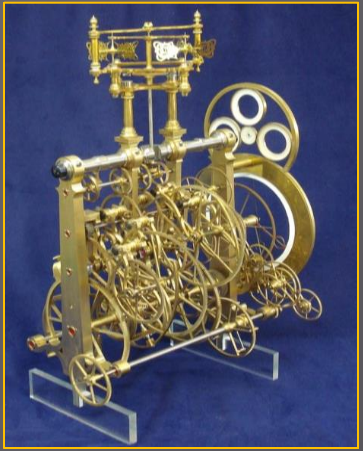
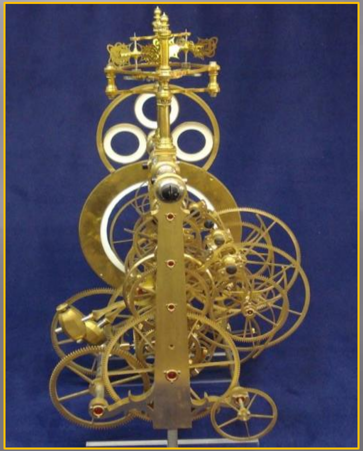
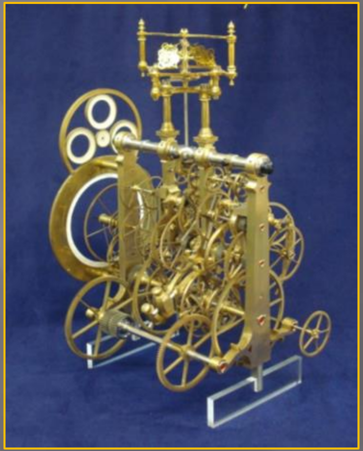
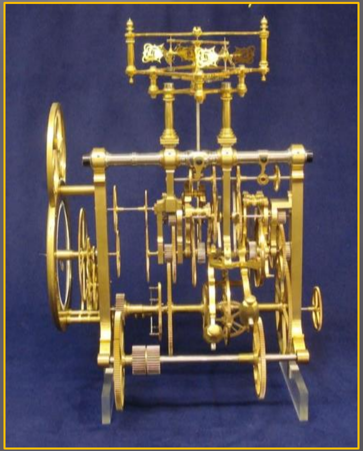




Great wheels and original frame plates

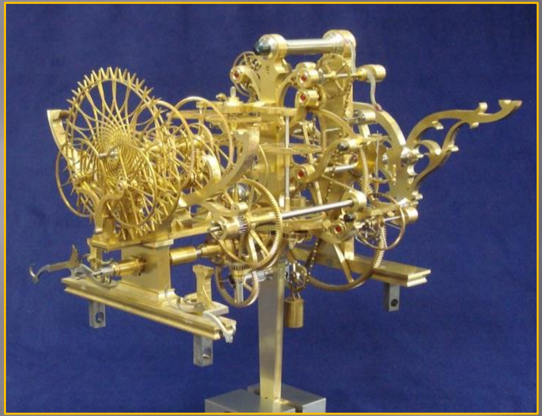
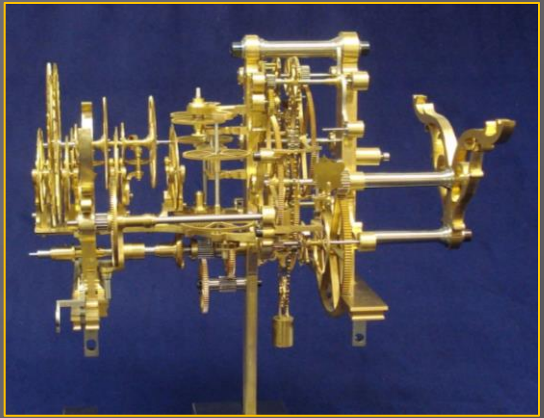
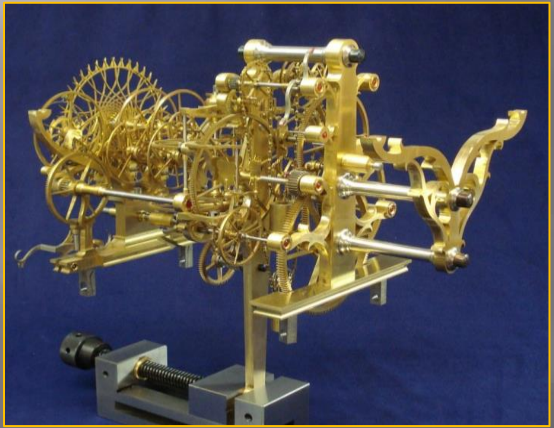


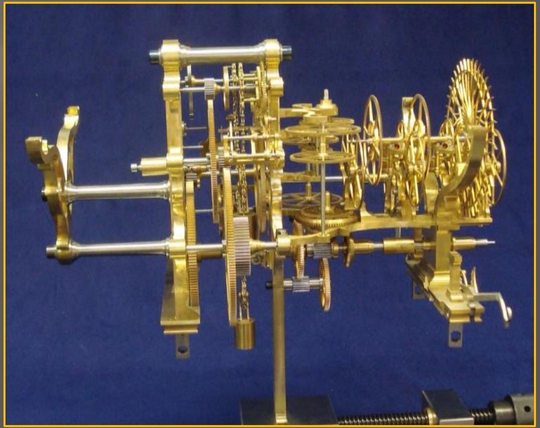
The first cut is made June 28, 2007, the last part was completed 15 years later. Next the main barrel wheels mounted between the plates. Each plate is ½″ thick and weighs 50 lbs.

Individual train modules, time train


Individual train modules, celestial train & escapement

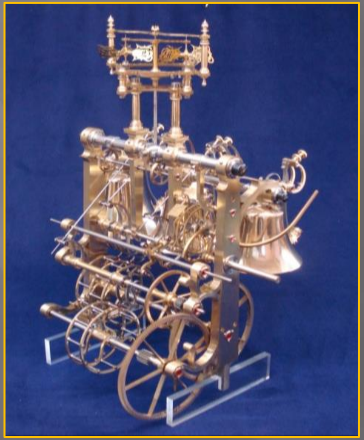







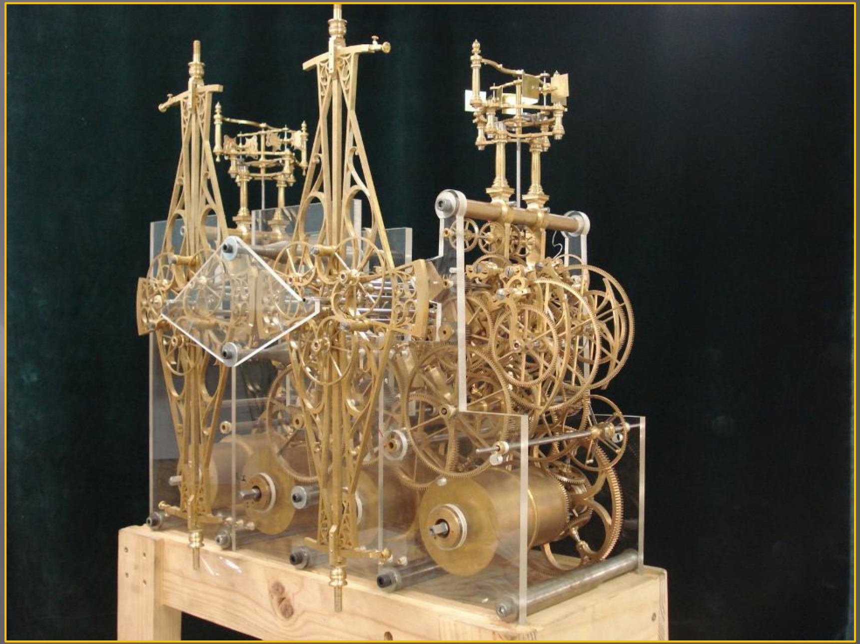
Individual train modules, quarter and hour strike trains





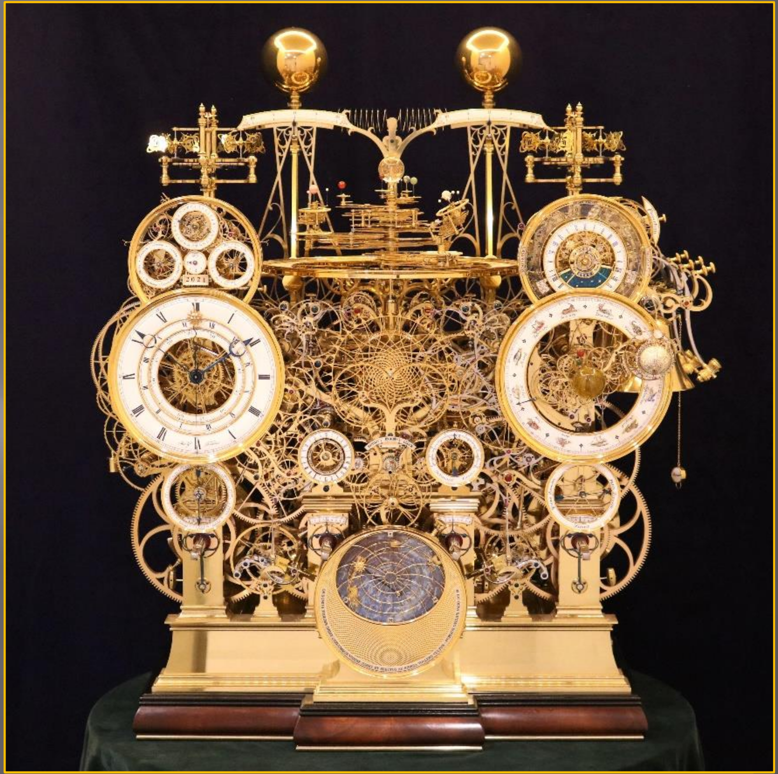



The build progresses using temporary plastic plates until 2009



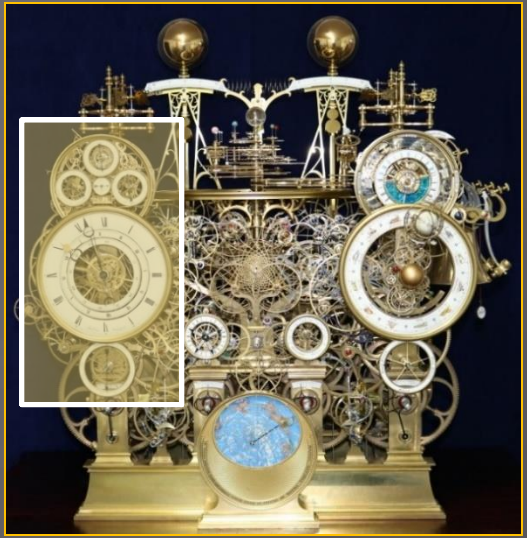
At this point we realize that a traditional plate and spacer frame design will not be practical, a new modular, pillar frame, left, is designed .

Where we are in 2022 compared to revised mockup of 2009



The machine has 71 complications. The main enamel dial work looks to be too sparse to support this many, that is intentional. Some makers have as many dials as possible to show off their complications, I preferred to allow the beauty of the machine to come to the fore. Too many dials look cluttered and confusing like the cockpit of an older analog jet airliner. There are many smaller subsidiary dials within.

List of complications, page 1



Complication count – 71 on dial data plus 5 special mechanical systems
Left hand dial cluster

Third-order 1200 year perpetual calendar dial cluster, 8

1. Day
2. Date
3. Month
4. Year
5. Leap year, four year correction-the first order
6. 100 year compensation, with dial
7. 400 year compensation, with dial
8. Calendar is fully reversible with no loss of data giving an 800 year span

Main time dial, 3

1. Equation of time
2. Sidereal time
3. True seconds readout derived from 2 second cycle pendulums "reverse" coup perdu

Equation setting dial, 2

1. Month,
2. Date

List of complications, page 2

Right hand dial cluster, Sun and Moon, rise and set

Sun section, 7

1. Time of sunrise/sunset
2. Visual position of sun in the sky
3. Mean solar time
4. Length of day
5. Length of night
6. Variable seasonal horizon shutters
7. Horizon season setting dial, annual calendar reads in real time

Moon section, 10

1. Visual indication of the phase of the Moon
2. Age of the Moon
3. Angle hour of the Moon
4. Degrees to moonrise
5. Degrees to moonset
6. Hours until moonrise (we have a double hour scale on the rotating glass degree scale, but stretched slightly compared to a conventional hour dial and the Moon rotates in the dial in 24 hours and 55 minutes). Zero hours is at the Moon and the hours count away from it, so the hours on the east, the horizon marker, gives you hours until moonrise.
7. Hours since moonrise
8. Hours since moonset
9. Great anomaly setting dial reads in real time
10. Projection anomaly setting dial reads in real time

List of complications, page 3

Tellurian, 15

1. Earth, Moon and Sun system, Sun also rotates
2. Additional inner planets of Mercury and Venus
3. Moon's orbital inclination in relation to Earth's ecliptic
4. Indication of Sun's zenith on the surface of the Earth
5. Tracking for Sun in each Zodiacal house
6. Date
7. Month
8. Synodic month sub dial
9. Sidereal month sub dial
10. Prediction of when as well as where on Earth a solar eclipse will occur
11. Prediction of when as well as where on Earth a lunar eclipse will occur
12. Location on Earth of Sun rise and set
13. Location on Earth of Moon rise and set
14. Location of the Sun through the Zodiac
15. Adjustable 3600 ring allowing user to set any point on earth as zero time, reading the time from any other point on the globe

Strike control, 3

1. Petite Sonnerie
2. Grande Sonnerie
3. Quarter repeat on demand in grande sonnerie
4. Strike and silent

List of complications, page 4

Orrery

Orrery, depiction of all known planets in the late 1700's, based on Philipp Hahn's design, 10

1. Planets Mercury to Saturn, with Jupiter and Saturn each having four and five orbiting moons respectively
2. Dials showing aphelion and perihelion and the orbital eccentricity for Mercury, Mars Jupiter and Saturn, and distance from the Sun in Astronomical units (AU) and millions of kilometers (Mkm)
3. Rotating Earth with Moon phase dial
4. Mass of each planet in terms of Earth (mE)
5. Planetary orbital time in years
6. Depiction of eccentricity of Mercury, Mars, Jupiter and Saturn's orbits
7. Planetary orbital distance from Sun in AU and Mkm (average for eccentric orbits, see #2)
8. Planetary tilt for Mars, Jupiter and Saturn in relation to the Sun's ecliptic
9. Position of all orrery components in degrees, 0-360° and position in the Zodiac
10. Two speed transmission for slow and fast demonstration

Lower center dial pair

International time dial, 1

1. Nine cities worldwide. Also used in astronomical demonstrations

Thermometer, 1

1. Reading in Fahrenheit and Celsius

List of complications, page 5

Bottom center dials

Planisphere dial, 4

1. Star plate with major star names, zodiacal houses, Milky Way overlay
2. Roving Sun showing travel through the Zodiac with seasonal height
3. in sky
3. Sun rise and set
4. Star sun rise and set

State of wind sector dials, 1

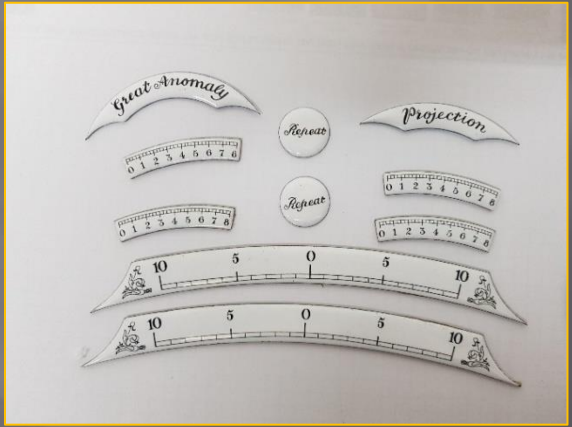
1. All four trains independently indicated with separate dial

Special mechanical complications, 7 and other interesting features

1. Dual Wagner style gravity remontoire driving the escapements, differential
2. Spring remontoire driving the perpetual calendar module, Jost Burgi
3. Robin endless chain remontoire for the celestial train, Robert Robin, based on Christian Huygen's design
4. Reverse *coup perdu* to derive single jump seconds from two second pendulums
5. Janvier-style slant wheel differentials within tumbling cages for Moon's orbital anomalies
6. Pendulum temperature compensation using Elinvar control springs

- Specialized compound fly fans designed to maximize visual sensation
- Paired, pirouetting style flies for the remontoire, releasing in 15 second intervals
- Epicyclical tourbillon flies based on Charles Fasoldt's design mediating the strike trains
- Celestial train remontoire fly releases in unequal intervals to keep the viewer guessing
- Sidereal time read off separate retrograde rotating rings for minutes and hours.
- All main trains and dial complications are independently removable.
- The machine is a dry runner ensuring long intervals between servicing.

Enamel dial work



Most scratch-built clocks do not use fired-enamel dial work as this is a specialized skill

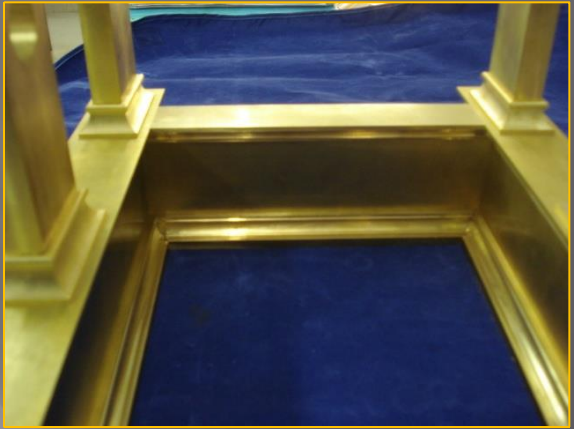
Enamel dial work

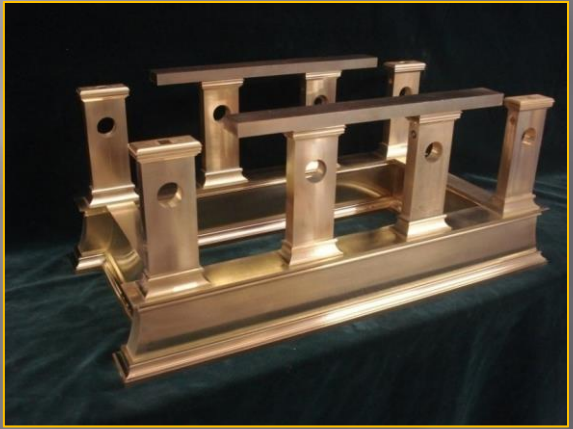
All dial art work was supplied by Buchanan and copied by the enamellers,. Planisphere was a 14″ Hand-painted original shrunk to 6.5″ by the enamellers. Dial bezels are plated in 24 ct. gold

Completed left and right side dial sets

Perpetual calendar, mean time, solar time, sidereal time, equation setting, world time
Sun-Moon rise/set, Moon phase/age, tellurian, strike control, thermometer

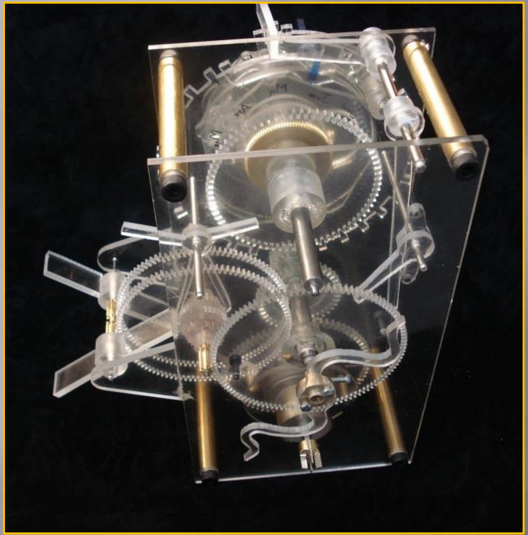
Lower movement frame assembly - detailing

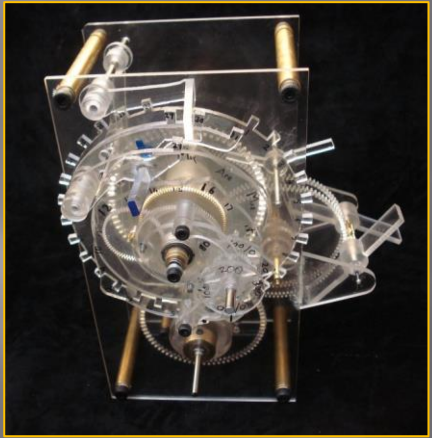


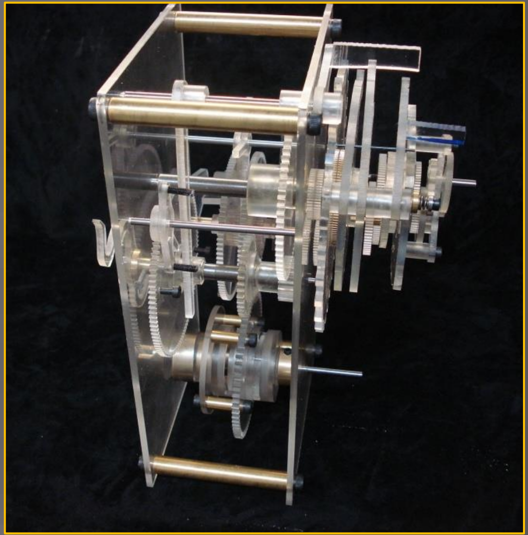


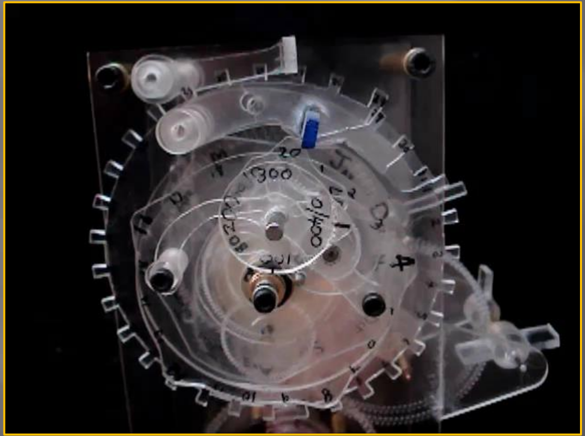
Lower movement frame, (excepting wheels) 126 parts

400 year calendar, functional mockup of perpetual module and its drive



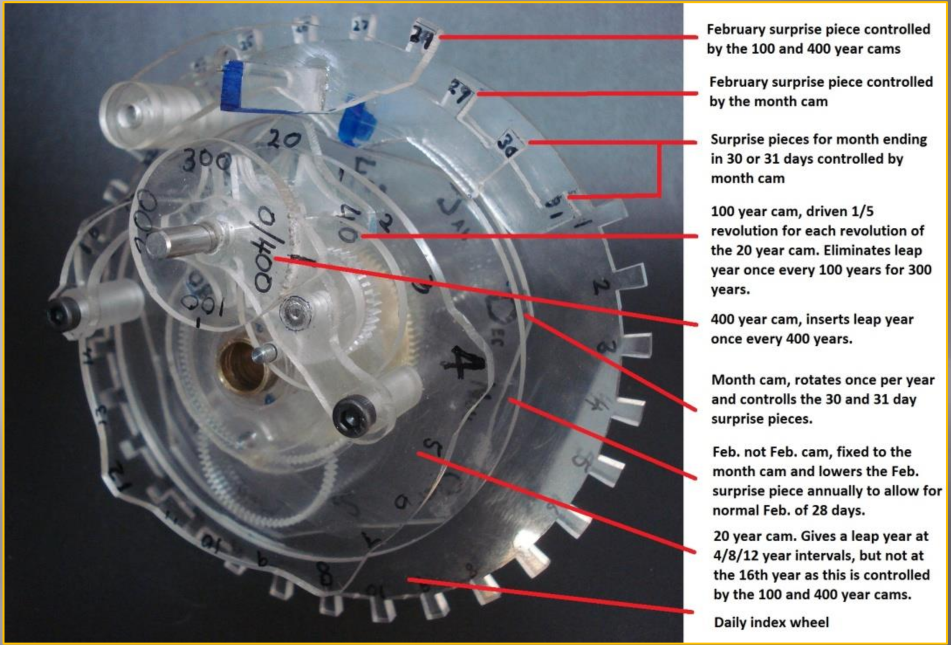


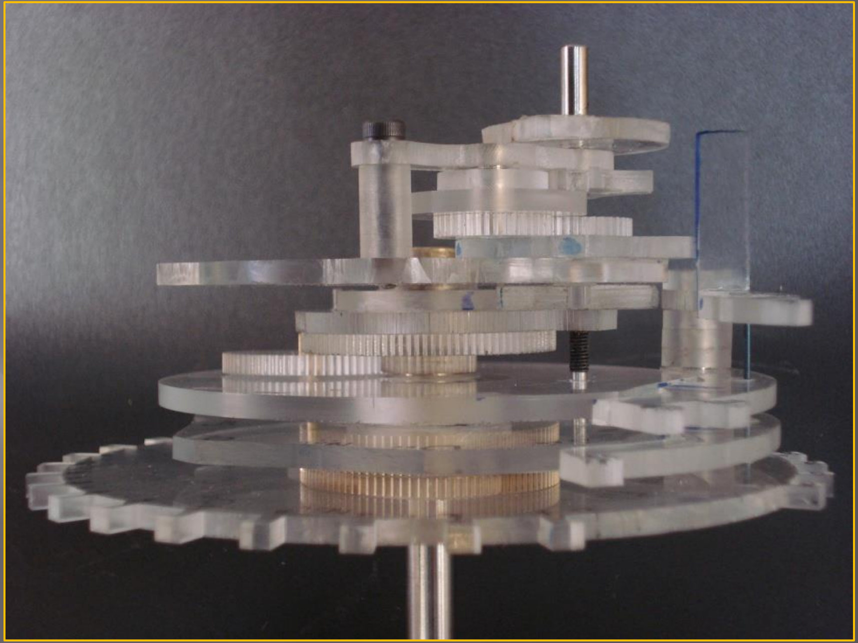




The perpetual module and its drive, fully functioning model in 1:3 ratio in plastic.

400 year calendar, third-order, reversible perpetual module





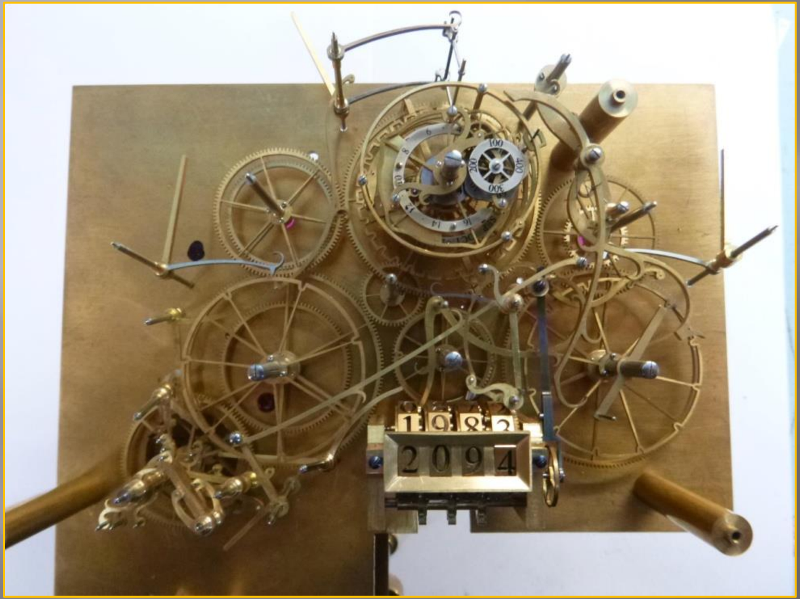
The third-order perpetual module keeps the Julian calendar perfectly in step with earth’s seasons for 1200 years. All data is preserved when moving from forward to reverse.

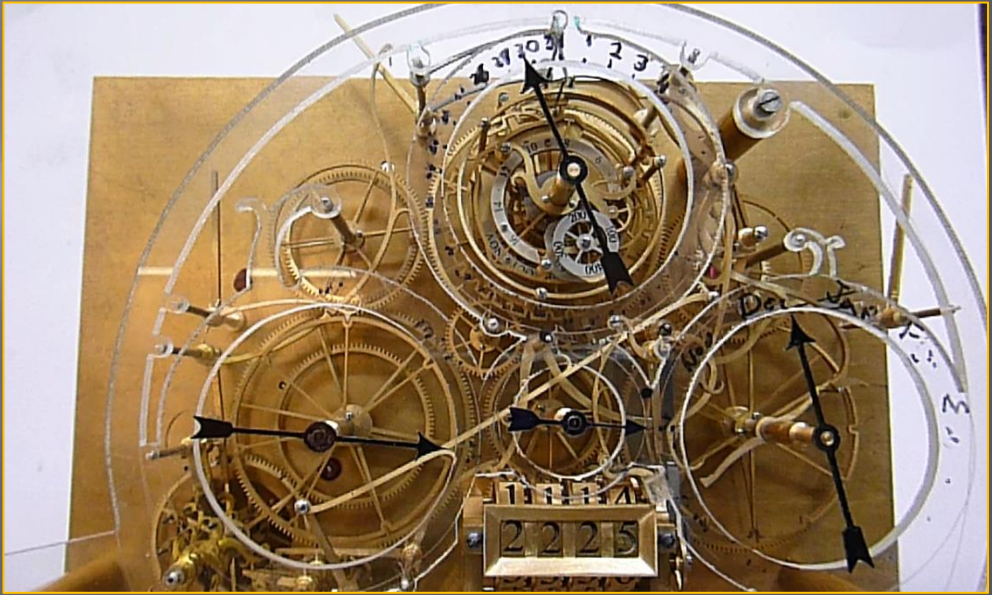
1st order, accounts for quadrennial leap years; days in months. This is perpetual calendar work in clocks

2nd order, 100 year cycle where leap year is skipped

3rd order, 400 year cycle where leap year is re-inserted

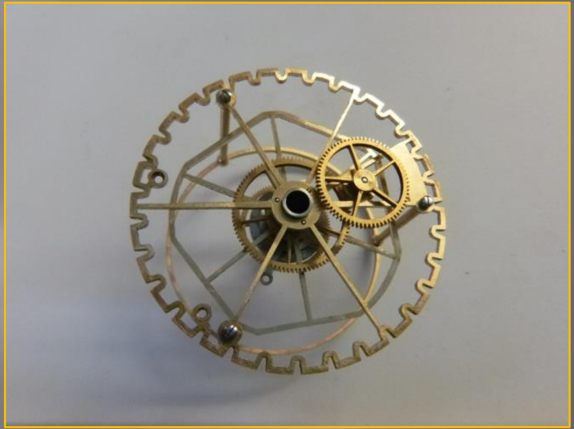
Calendar components in place





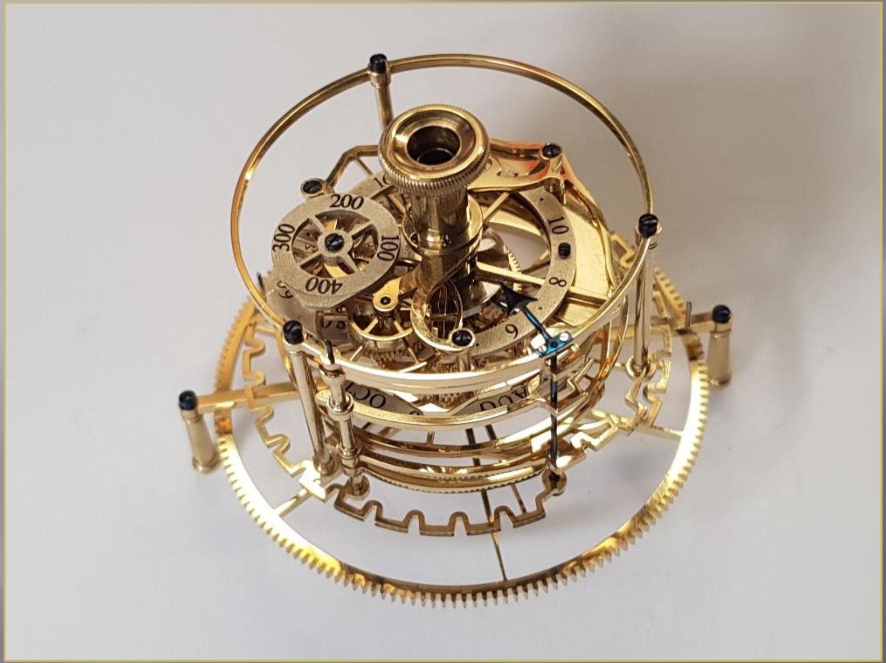
The calendar year readout is digital and uses a ten-sided component to give a flat readout surface.

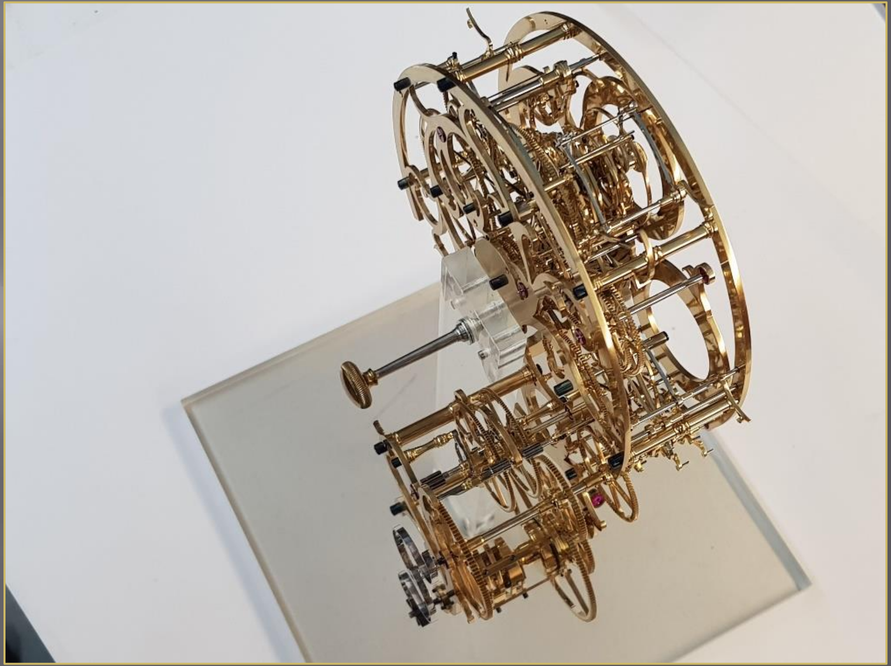
400 year calendar, perpetual module



Components of the perpetual module on the scale of pocket watch work; the limit of Buchanan's tooling

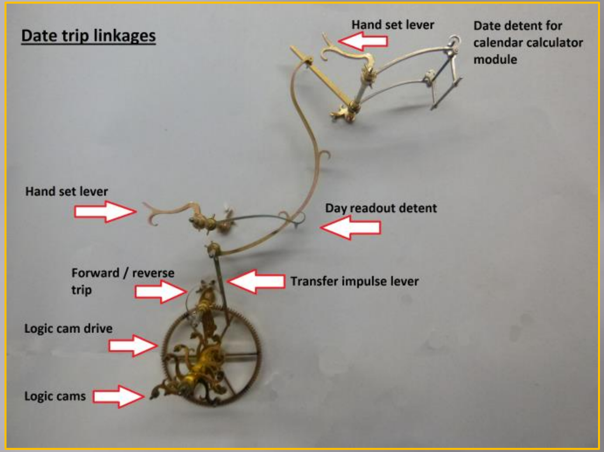
Final polishing and assembly

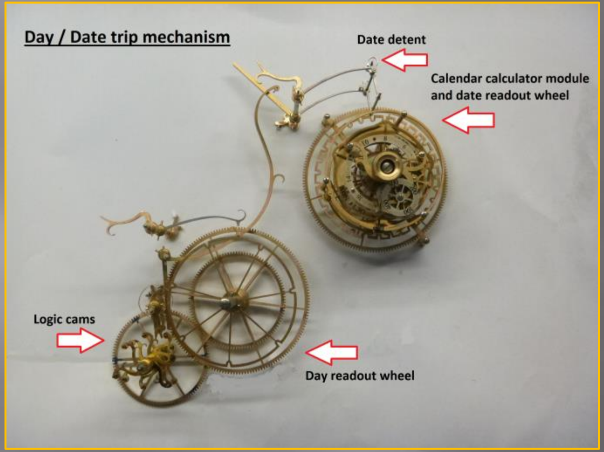


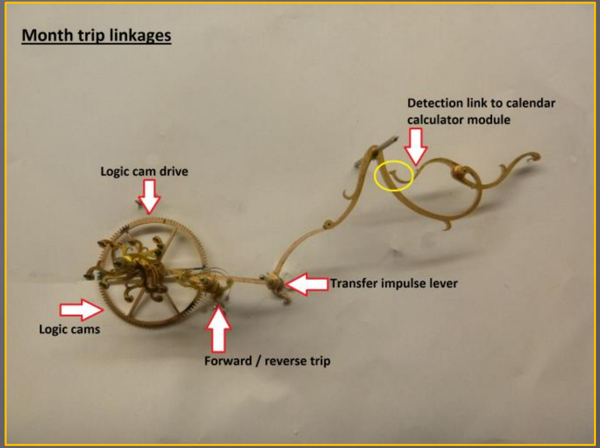


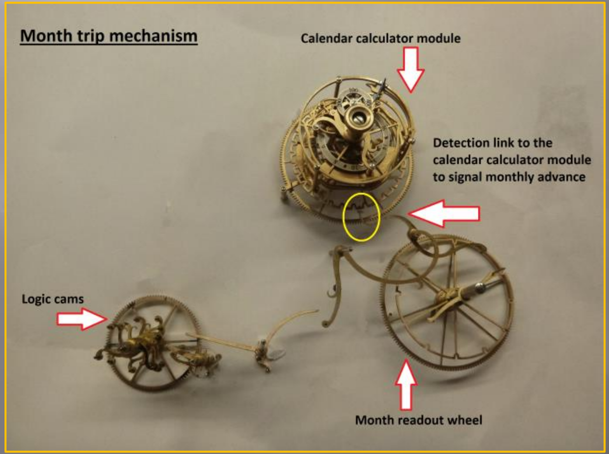
The calendar cam memory with French silvered setting dials for the 100 and 400 year cam settings and full module finished and ready for installation.

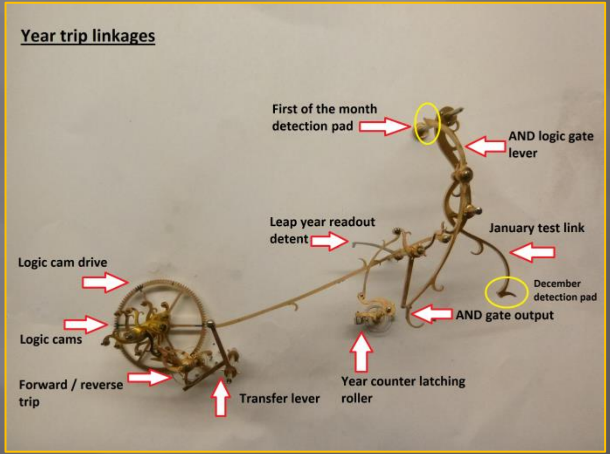
Calendar calculator componets

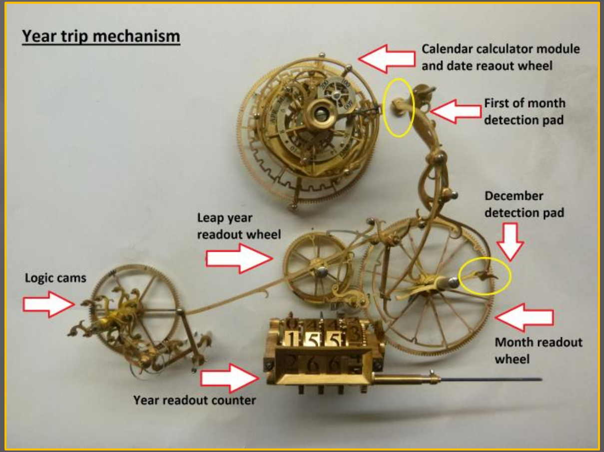






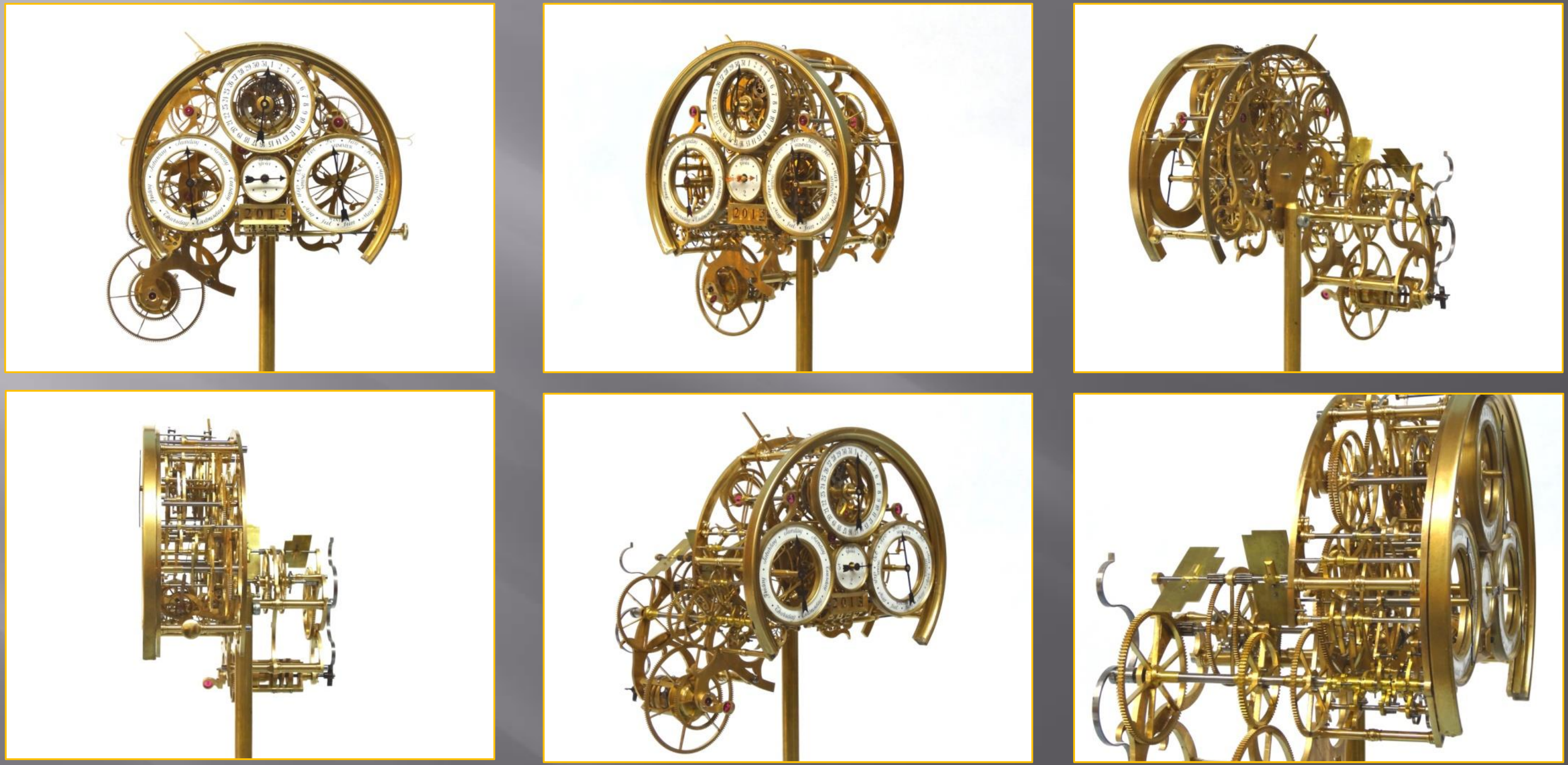






The calendar is a small computer, it can store, retrieve and process data.

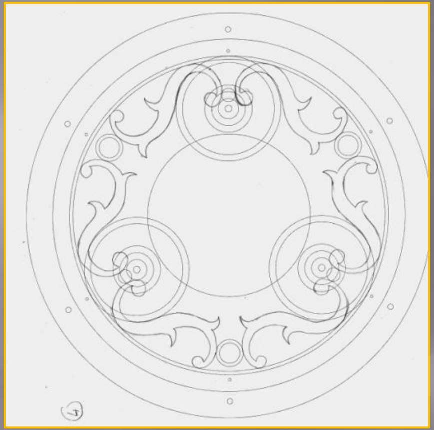
Completed calendar module



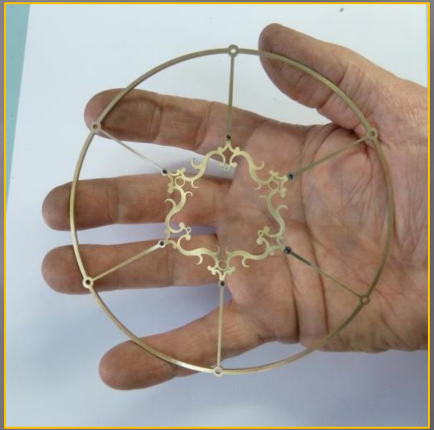
580 parts , 8 months design and fabrication time

400 year, third-order, reversible perpetual calendar dial work

Sidereal time retrograde dial readouts fabrication

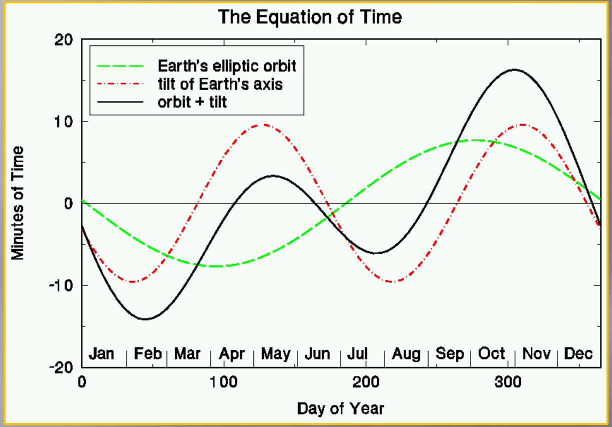



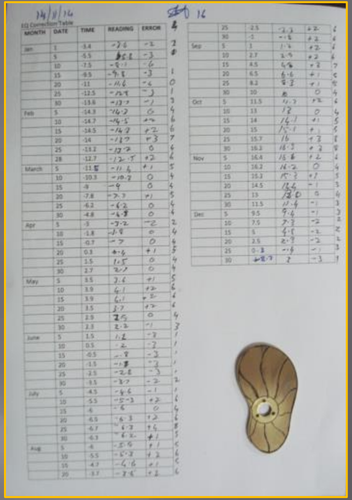




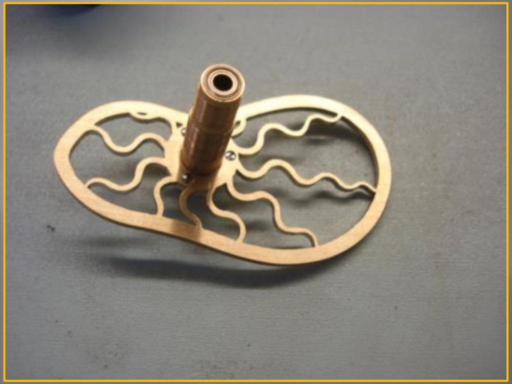
Artistry in metal

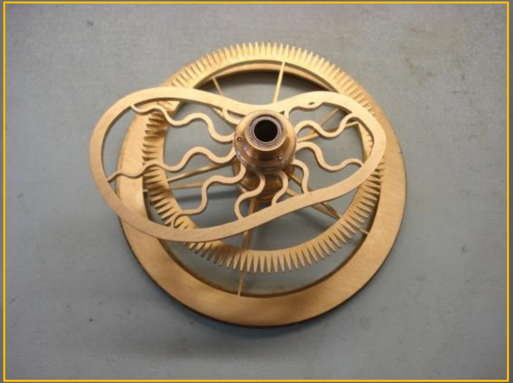
Equation of time work

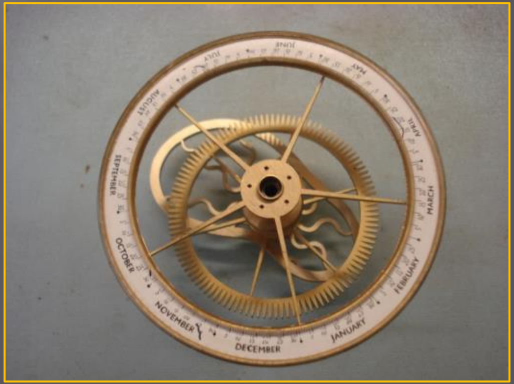




73 points x 5 days = 365 days
16 iterations x 73 points =1168 tests



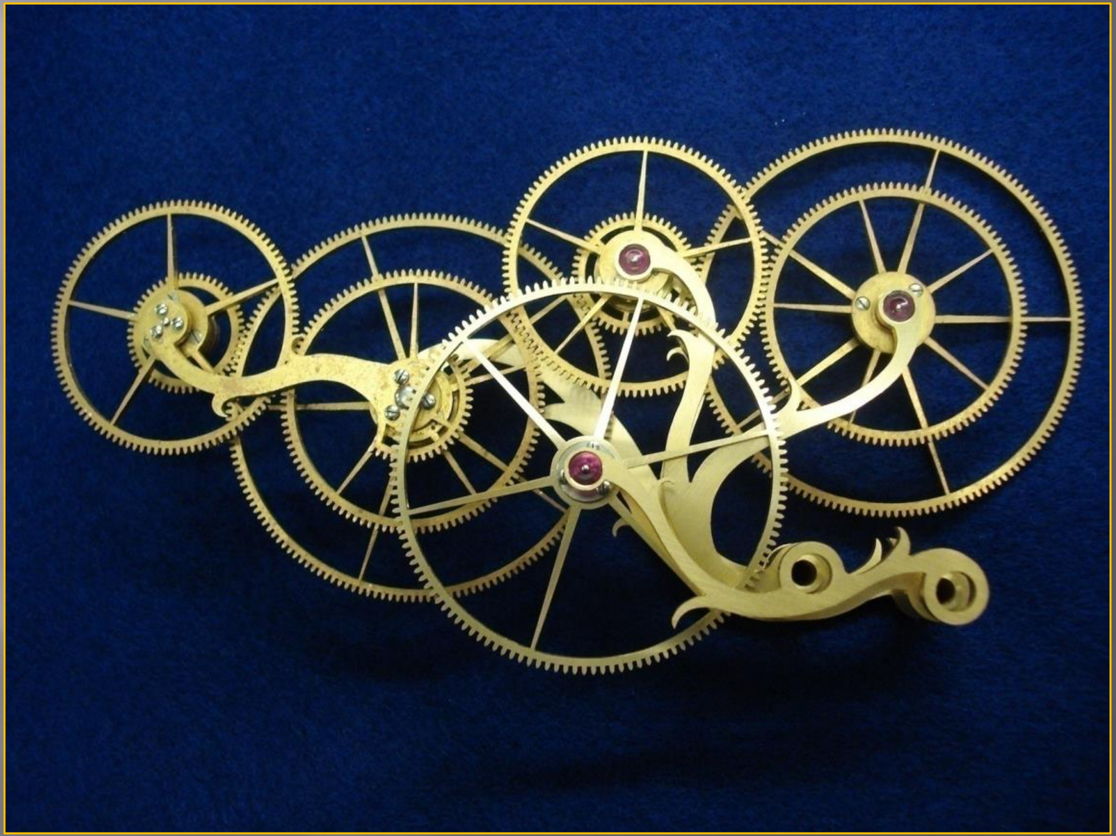




Mean solar, solar and sidereal time's retrograde dial work

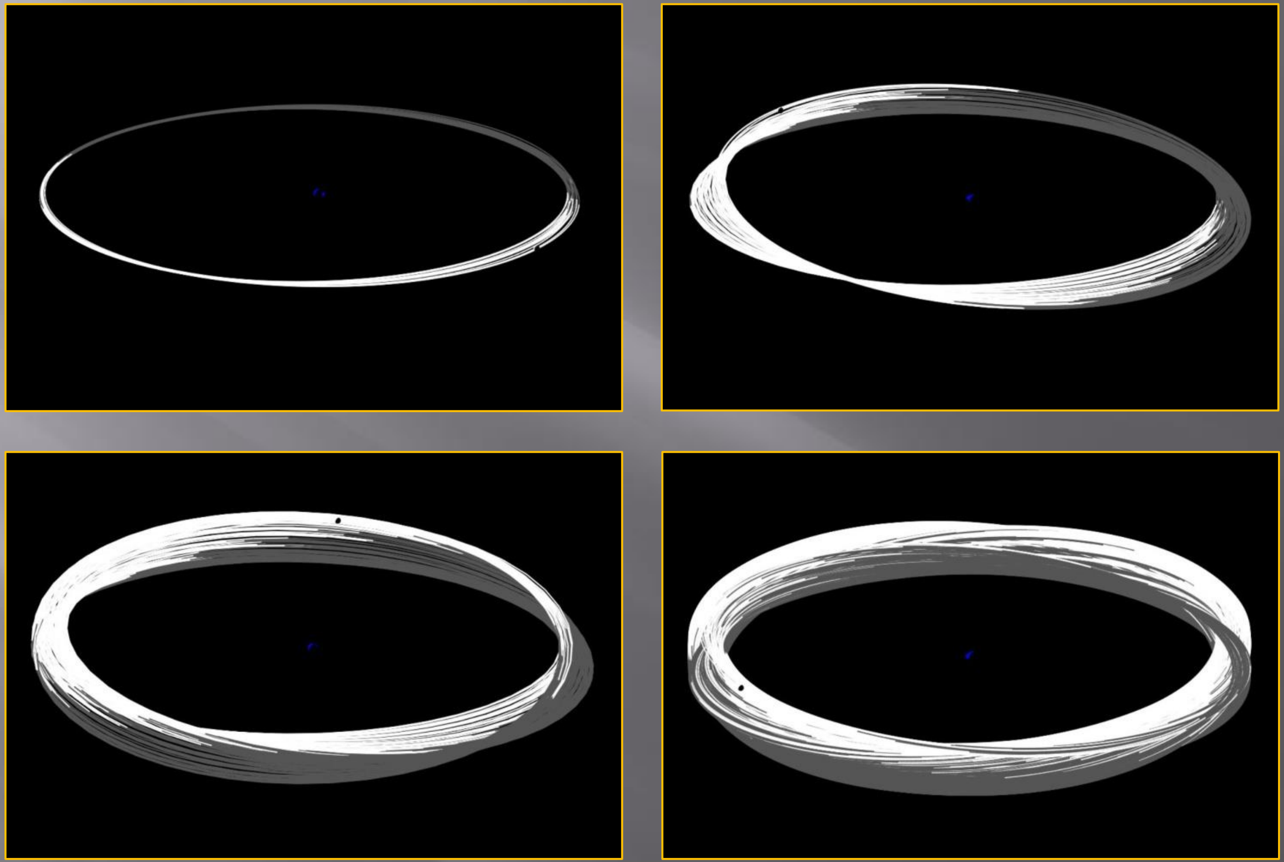
The main dial allows for direct readings between mean solar, equation and sidereal times

Equation of time work



Equation of time differential, less kidney cam; assembled

Time of Sun and Moon rise/set, 1



Path of moon's orbit, 1, 5, 10 and 60 years

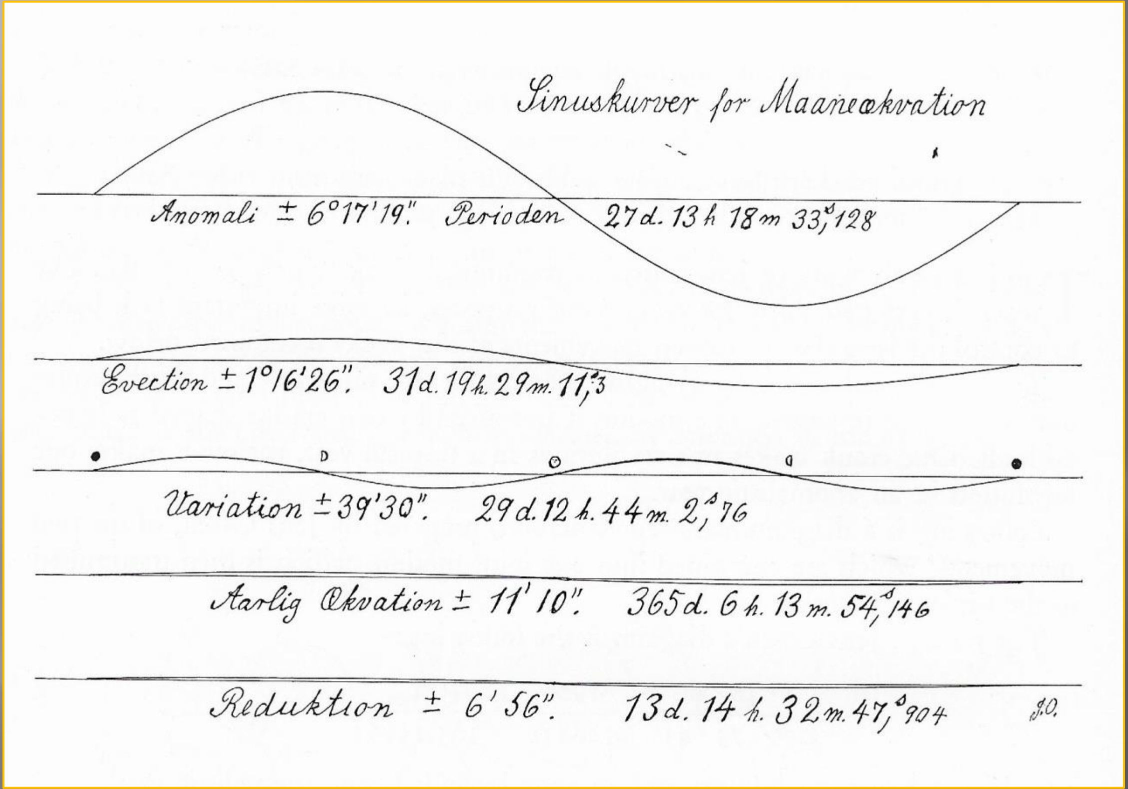
Time of Sun and Moon rise/set, 2

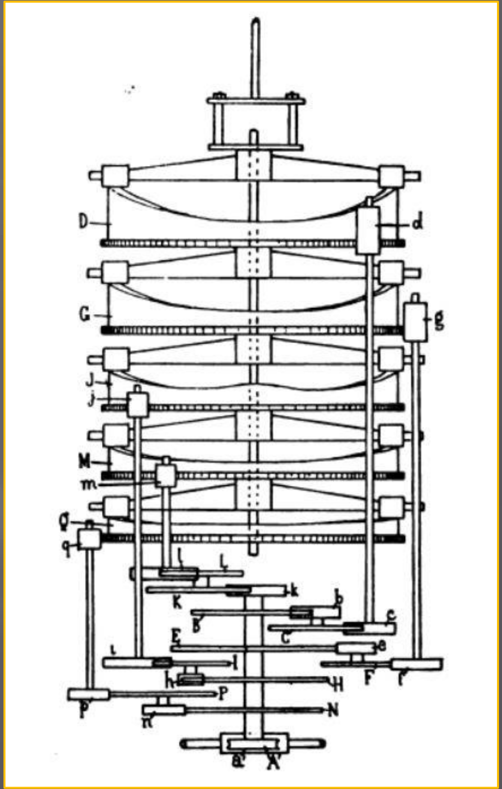
1. **Great Anomaly**: This is the effect of the Moon’s elliptical orbit around the Earth and has a ±.6.58° equaling 26.322 minutes effect every anomalistic month which is defined as the time between the Moon's successive perigees and is approximately 27.55 days.
2. **Evection**: This is the change in the Moon's ecliptic longitude: This is caused by the gravitational pull of the Sun and Earth which causes the Moon to accelerate as it moves toward and decelerate as it moves away from the Sun. The period is 31.81 days. This is ± 1.274° equaling 5.097 minutes.
3. **Variation**: The combined effect of the Sun and Earth on the Moon's orbit at lunar conjunction (when the Earth, Moon and Sun, in that order, are in alignment) and at lunar opposition (when the Moon, Earth and Sun, in that order, are in alignment). The Variation is ±0.658° equaling 2.632 minutes and has a period of half a synodic month or 14.77 days commonly known as a lunar month which is 29.531 days.
4. **Annual Equation**: This is ±0.186° equaling 0.856 minutes and has the period of one anomalistic year or 365.26 days. It is the combined influence of the Sun and Earth on the Moon owing to the Earth’s elliptical orbit.
5. **Reduction:** This is ±0.214° equaling 0.8569 minutes and has a period of one-half the anomalistic month or 13.77 days and is due to the tilt of the Moon's orbit of 5.8° to the ecliptic.

However to truly show when the Moon will rise and set two additional corrections are needed, these are associated with the Earth and its orbit, and to a very minor extent the Sun itself.

6. **Projection**: Two factors are needed to account for the Earth's 23.5° tilt from the ecliptic as well as it's elliptical orbit around the Sun. These factors are the same as those needed to compute the equation of time. The projection is ±2.464° which translates into about ±9.857 minutes in time. It has a period of one-half the tropical month or 13.661 days.
7. **Solar Equation**: This encompasses a further two very minor anomalies associated with the Sun

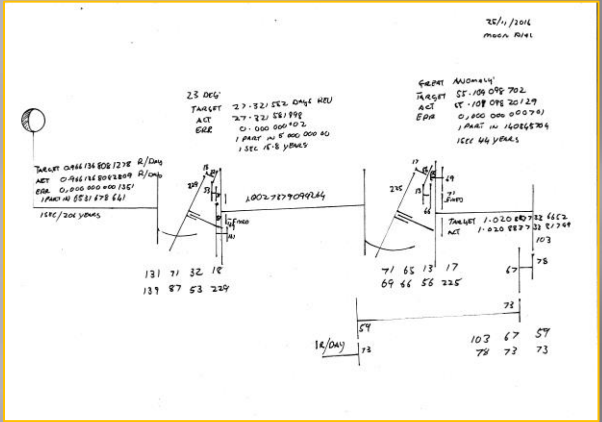
Time of Sun and Moon rise/set, 3

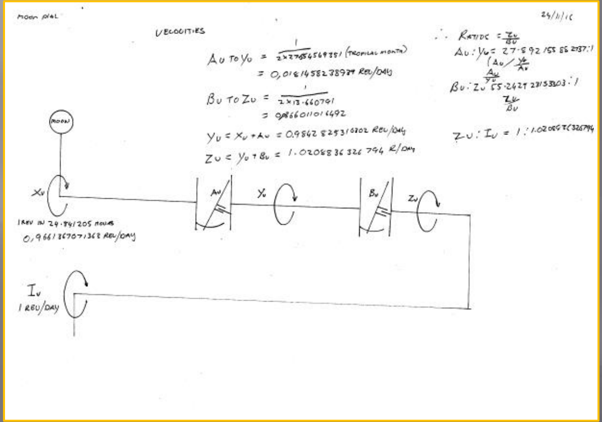


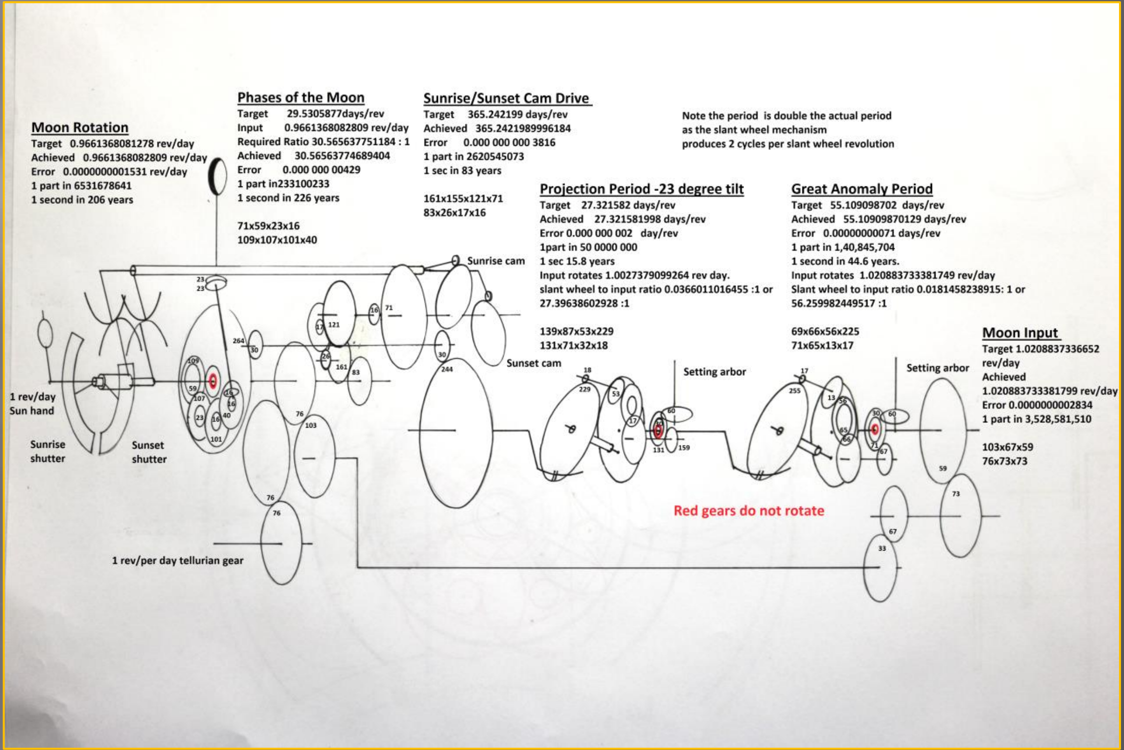


Graphical representation of five moon orbital anomalies, and then made into cam works

Time of Sun and Moon rise/set, 4



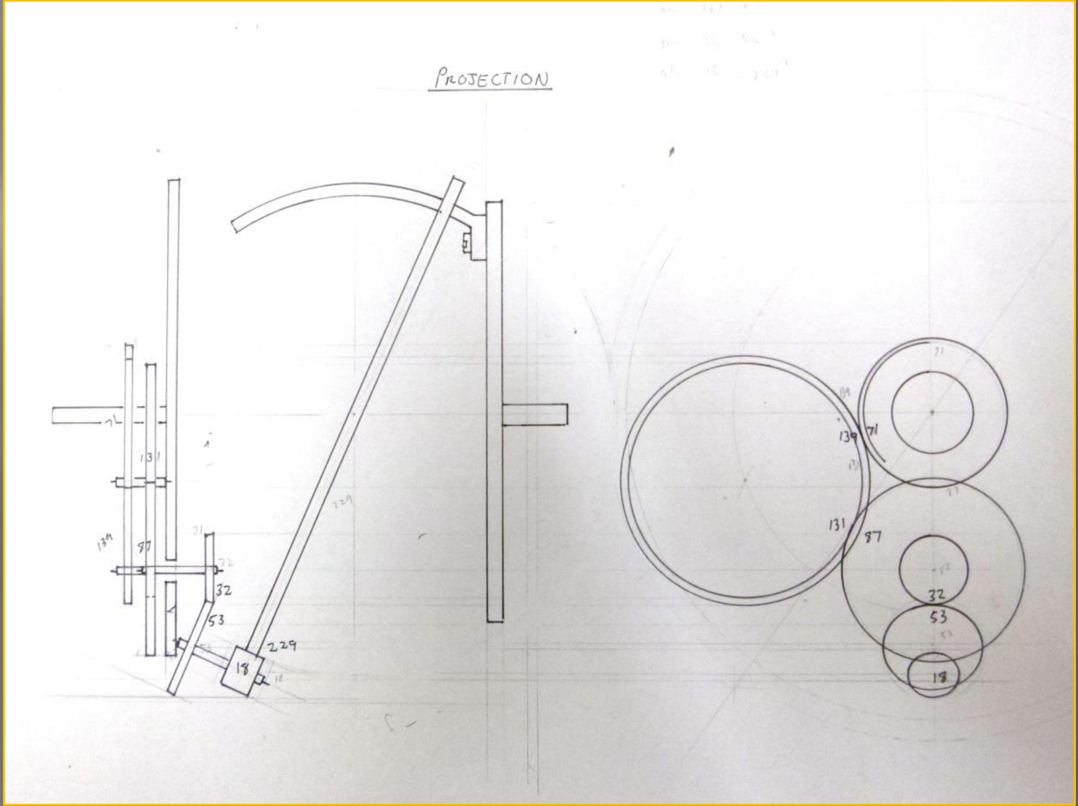




Buchanan’s design for four anomalies, two months design time.

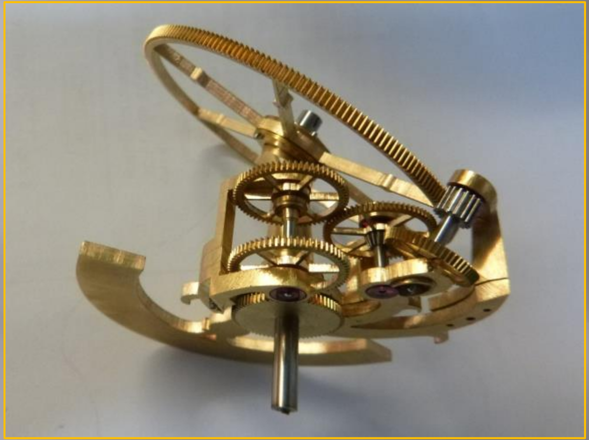
Time of Sun and Moon rise/set, 5

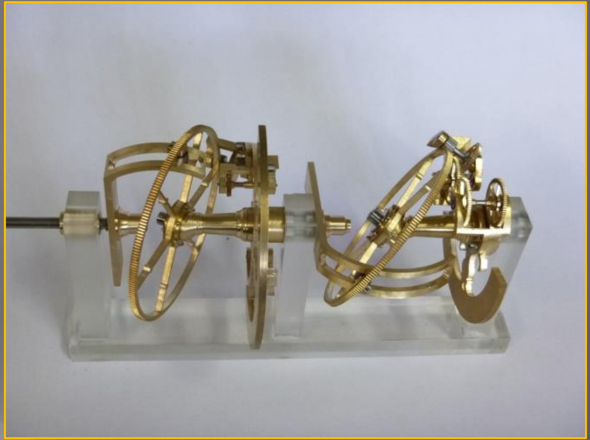
Position		Number of teeth	Size cutter	Blank diameter	Pitch circle diameter	Depthing
Infeed	1	103	0.35	37.016	36.05	18.025
	2	78	0.35	28.266	27.3	13.65
	3	67	0.35	24.416	23.45	11.725
	4	73	0.35	26.516	25.55	12.775
	5	59	0.35	21.616	20.65	10.325
	6	73	0.35	26.516	25.55	12.775
Great anomaly	1	225	0.3	68.328	67.5	33.75
	2	17	0.3	5.928	5.1	2.55
	3	71	0.25	18.44	17.75	8.875
	4	69	0.25	17.94	17.25	8.625
	5	65	0.25	16.94	16.25	8.125
	6	66	0.25	17.19	16.5	8.25
	7	13	0.25	3.94	3.25	1.625
	8	56	0.25	14.69	14	7
Projection	1	229	0.3	69.528	68.7	34.35
	2	18	0.3	6.228	5.4	2.7
	3	131	0.25	33.44	32.75	16.375
	4	139	0.25	35.44	34.75	17.375
	5	71	0.25	18.44	17.75	8.875
	6	87	0.25	22.44	21.75	10.875
	7	32	0.25	8.69	8	4
	8	53	0.25	13.94	13.25	6.625
Moon phases	1	71	0.25	18.44	17.75	8.875
	2	109	0.25	27.94	27.25	13.625
	3	59	0.25	15.44	14.75	7.375
	4	107	0.25	27.44	26.75	13.375
	5	23	0.25	6.44	5.75	2.875
	6	101	0.25	25.94	25.25	12.625
	7	16	0.25	4.69	4	2
	8	40	0.25	10.69	10	5
Sun rise/set cam drive	1	83	0.25	21.44	20.75	10.375
	2	161	0.3	49.128	48.3	24.15
	3	26	0.3	8.628	7.8	3.9
	4	155	0.25	39.44	38.75	19.375
	5	17	0.25	4.94	4.25	2.125
	6	121	0.25	30.94	30.25	15.125
	7	16	0.25	4.69	4	2
	8	71	0.25	18.44	17.75	8.875
sun rise/set quadrents	1		0.3	0.828	0	0
	2		0.3	0.828	0	0
	3		0.3	0.828	0	0
	4		0.3	0.828	0	0
Sun drive wheel	1		0.4	1.104	0	0
Moon arm drive wheels	1	244	0.35	86.366	85.4	42.7
	2	244	0.35	86.366	85.4	42.7
	3	30	0.35	11.466	10.5	5.25
	4	30	0.35	11.466	10.5	5.25
Primery input idler.	1		0.4	1.104	0	0

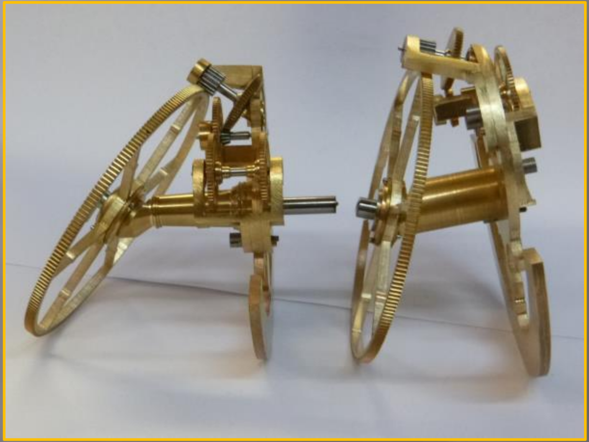


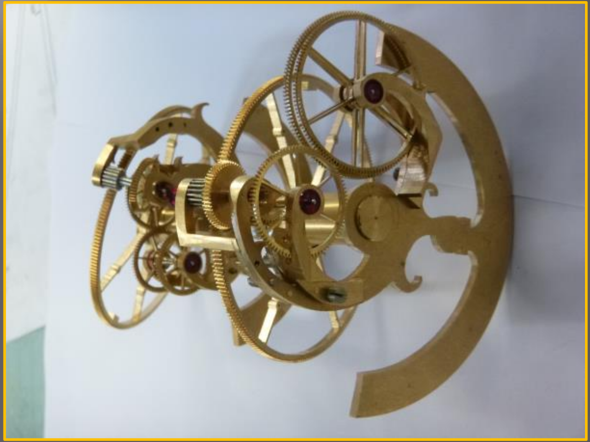
The gear table encompasses over 50 wheels for this module. The Projection variable differential.

Time of Sun and Moon rise/set, 6



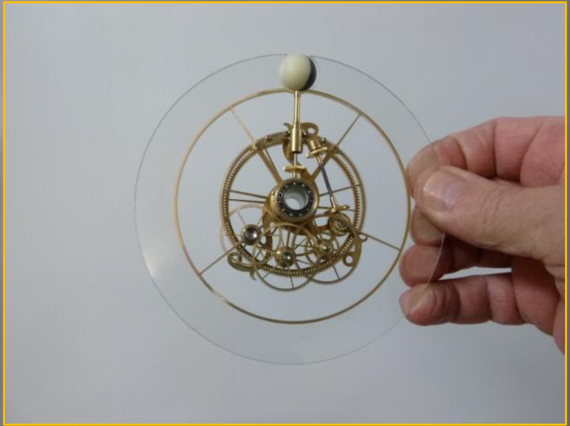






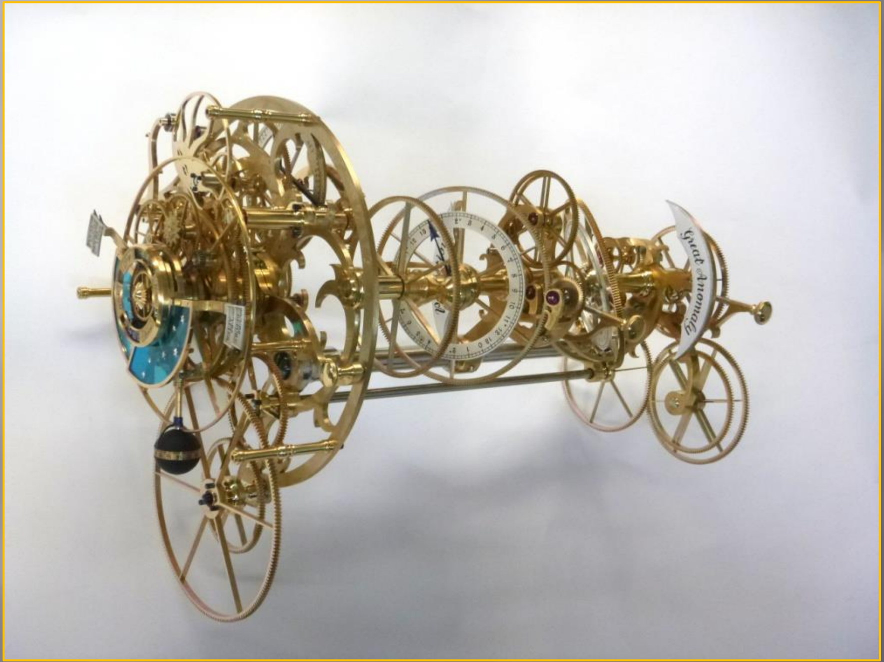
Pair of Janvier's design of slant-wheel variable differentials that correct for the Moon's orbital anomalies.

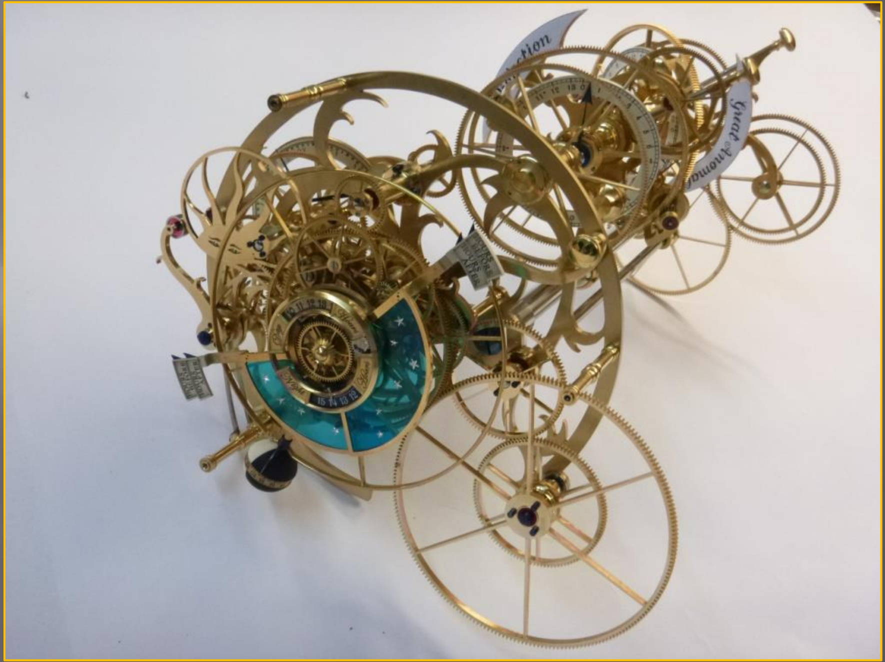
Time of Sun and Moon rise/set, 7



Time of Sun and Moon rise/set, 8

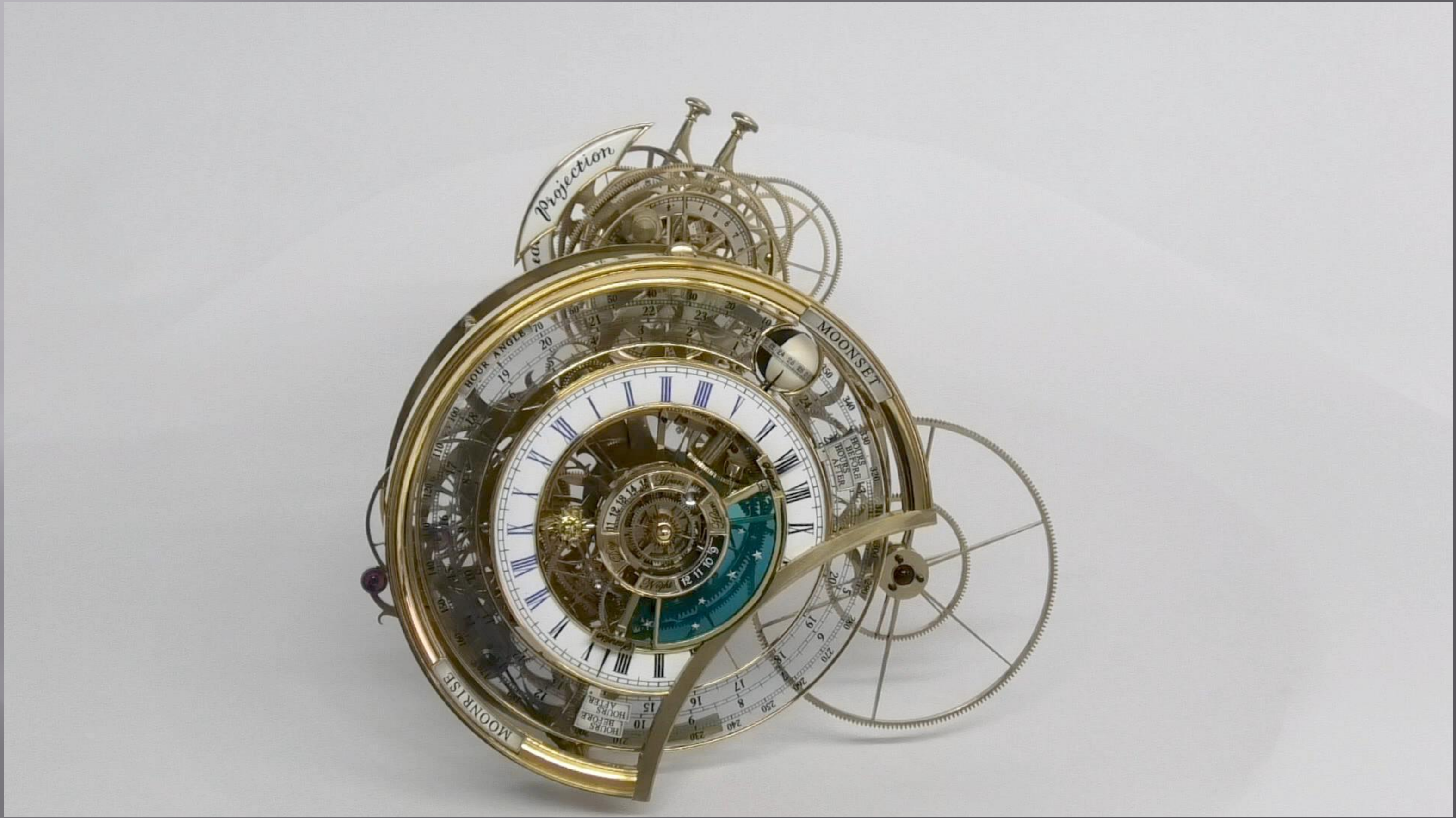
Time of Sun and Moon rise/set, 9





550 parts , 12 months design and fabrication time

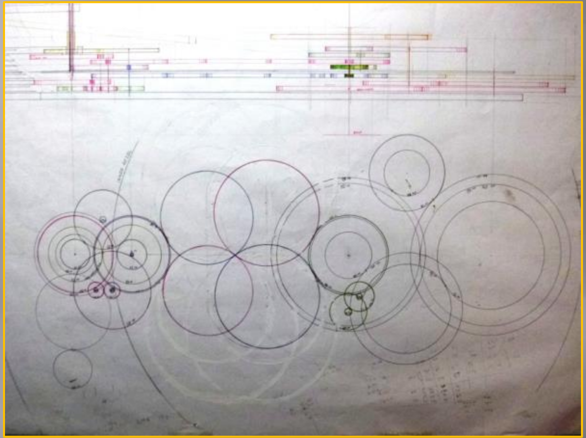
Final polishing and assembly, Sun/Moon-rise/set

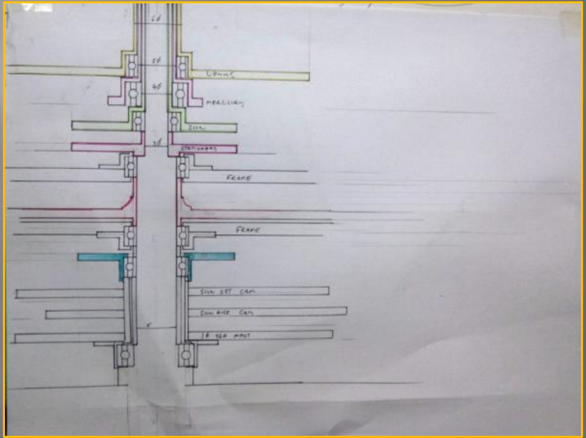


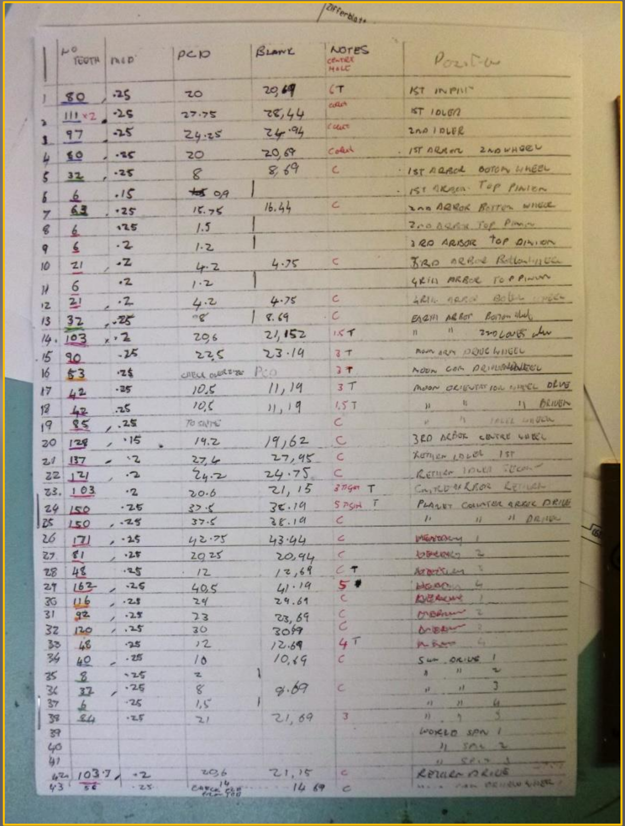
Time of Sun and Moon rise/set dial work

This one dial reads 17 complications, (see slide #9) and is an example of using the minimum number of dials to present the maximum number of complications.

Tellurian





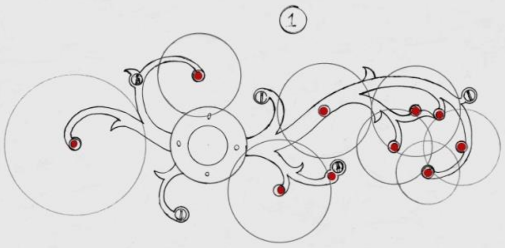


Zifferblatt

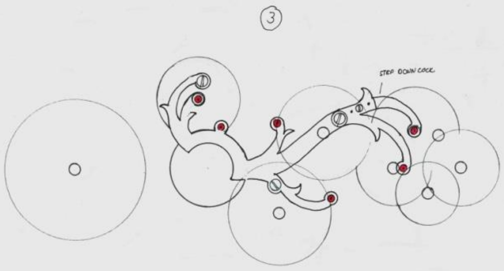
	No TEETH	MOD	PCD	BLANK	NOTES CENTRE HOLE	POSITION
1	80	.25	20	20,69	6T	1ST INPUT
2	111 ×2	.25	27.75	28,44	[illegible]	1ST IDLER
3	97	.25	24.25	24.94	[illegible]	2ND IDLER
4	80	.25	20	20,69	[illegible]	1ST ARBOR 2ND WHEEL
5	32	.25	8	8,69	C	1ST ARBOR BOTOM WHEEL
6	6	.15	0,9			1ST ARBOR TOP PINION
7	63	.25	15.75	16.44	C	2ND ARBOR BOTTOM WHEEL
8	6	.25	1.5			2ND ARBOR TOP PINION
9	6	.2	1.2			3RD ARBOR TOP PINION
10	21	.2	4.2	4.75	C	3RD ARBOR BOTTOM WHEEL
11	6	.2	1.2			4TH ARBOR TOP PINION
12	21	.2	4.2	4.75	C	4TH ARBOR BOTTOM WHEEL
13	32	.25	8	8.69	C	EARTH ARBOR Bottom wheel
14	103	.2	20,6	21,152	1.5T	" " 2ND LOWER wheel
15	90	.25	22,5	23.19	3T	MOON ARM DRIVE WHEEL
16	53	.25	CHECK OVERSIZE PCD		3T	MOON CAM DRIVEN WHEEL
17	42	.25	10.5	11,19	3T	MOON ORIENTATION WHEEL DRIVE
18	42	.25	10,5	11,19	1.5T	" " " DRIVEN
19	85	.25	TO SUIT		C	" " IDLER WHEEL
20	128	.15	14.2	19,62	C	3RD ARBOR CENTRE WHEEL
21	137	.2	27,4	27,95	C	RETURN IDLER 1ST
22	121	.2	24.2	24.75	C	RETURN IDLER SECOND
23	103	.2	20.6	21,15	[illegible] T	CENTRE ARBOR RETURN
24	150	.25	37.5	38.19	[illegible] T	PLANET COUNTER ARBOR DRIVE
25	150	.25	37.5	38.19	C	" " " DRIVEN
26	171	.25	42.75	43.44	C	MERCURY 1
27	81	.25	20.25	20,94	C	MERCURY 2
28	48	.25	12	12,69	C T	MERCURY 3
29	162	.25	40.5	41.19	5	MERCURY 4
30	116	.25	29	29.69	C	[illegible] 1
31	92	.25	23	23,69	C	[illegible] 2
32	120	.25	30	30,69	C	[illegible] 3
33	48	.25	12	12.69	4T	[illegible] 4
34	40	.25	10	10,69	C	SUN DRIVE 1
35	8	.25	2			" " 2
36	37	.25	8	8.69	C	" " 3
37	6	.25	1,5			" " 4
38	84	.25	21	21,69	3	" " 5
39						WORLD SPIN 1
40						" SPIN 2
41						" SPIN 3
42	103.7	.2	20.6	21,15	C	RETURN DRIVE
43	56	.25	CHECK 14 [illegible]	14.69	C	[illegible] CAM DRIVEN WHEEL

Calculation sheet for wheel configurations, 63.

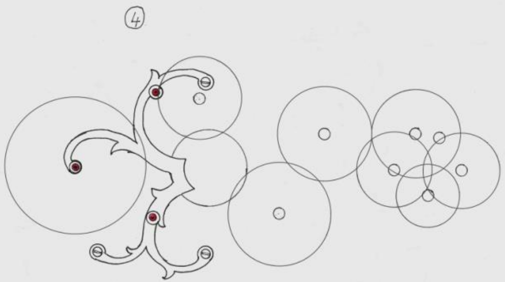
Tellurian



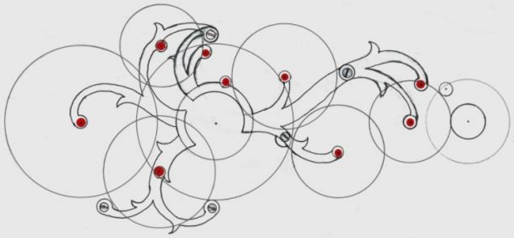
Lower frame



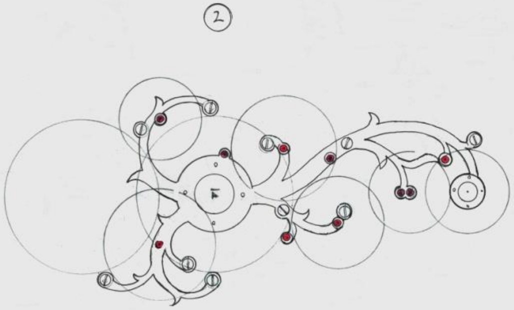
Upper sub-frame, right



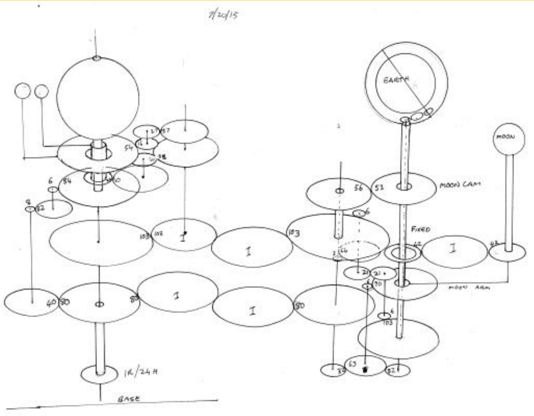
Upper sub-frame, left



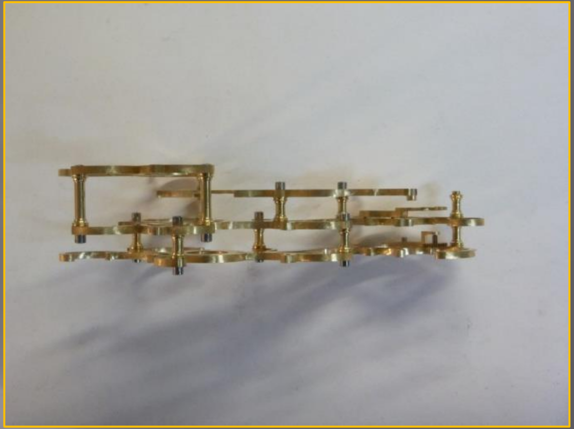
Upper sub-frames, left and right



Middle frame

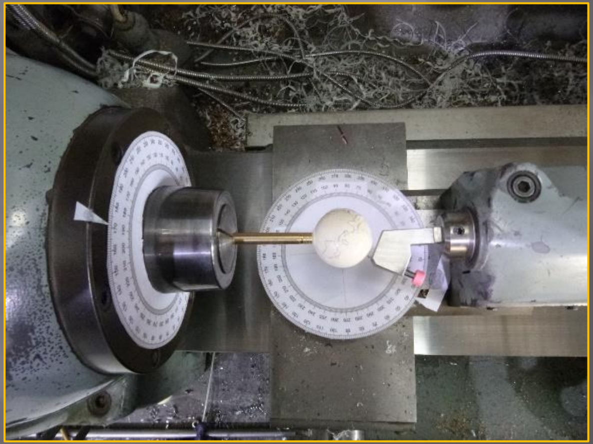


Tellurian



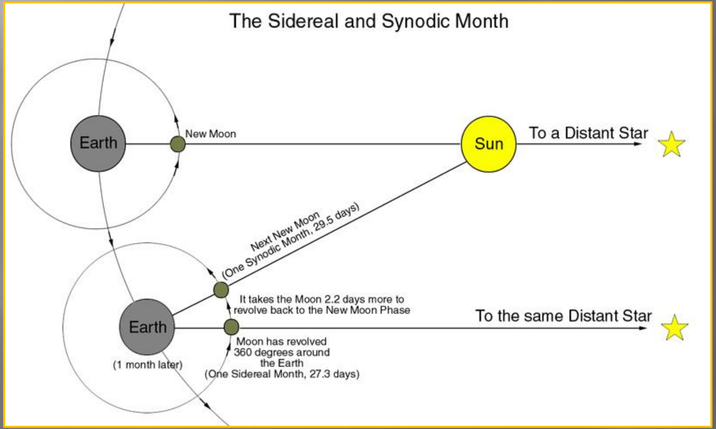
Tellurian double frame assembly

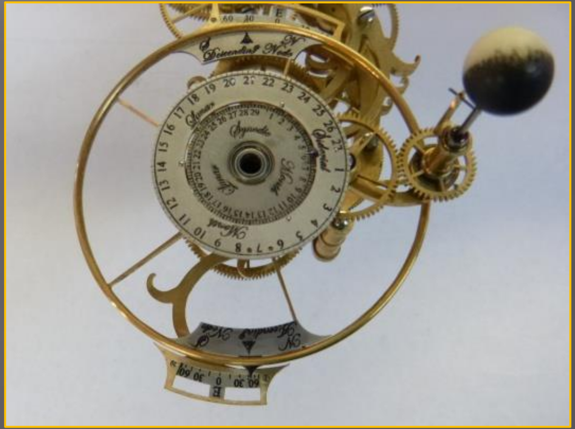
Tellurian



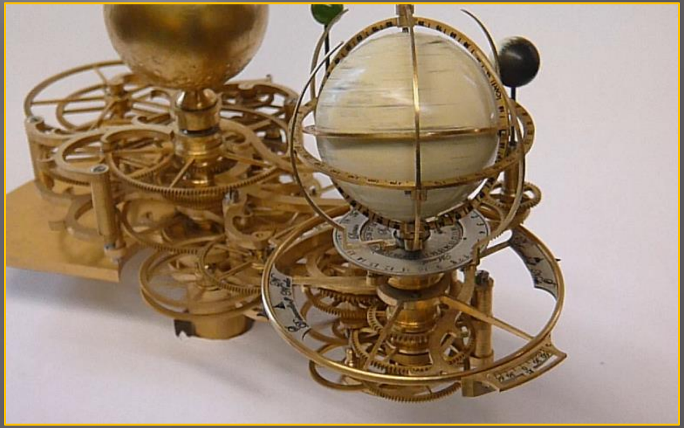
Tellurian Earth globe made from Mammoth ivory

Tellurian


The Sidereal and Synodic Month
Earth
New Moon
Sun
To a Distant Star
Next New Moon
(One Synodic Month, 29.5 days)
It takes the Moon 2.2 days more to
revolve back to the New Moon Phase
Earth
(1 month later)
To the same Distant Star
Moon has revolved
360 degrees around
the Earth
(One Sidereal Month, 27.3 days)



Tellurian

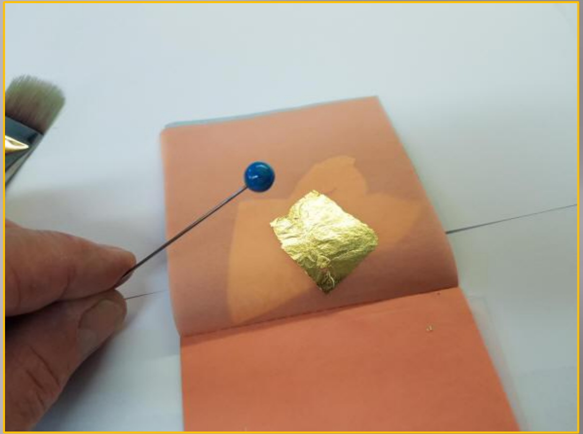


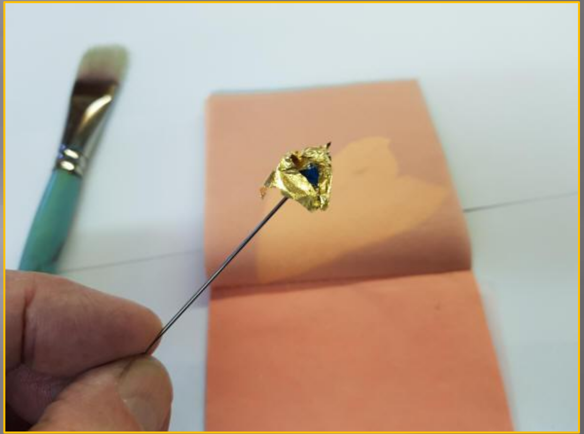
395 parts, 30 jewels, 6 months design and fabrication time

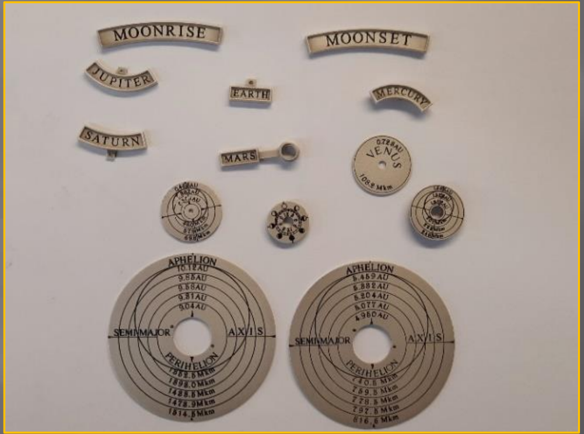
Tellurian dial

Semi-precious stones used in the orrery and tellurion

The orrery



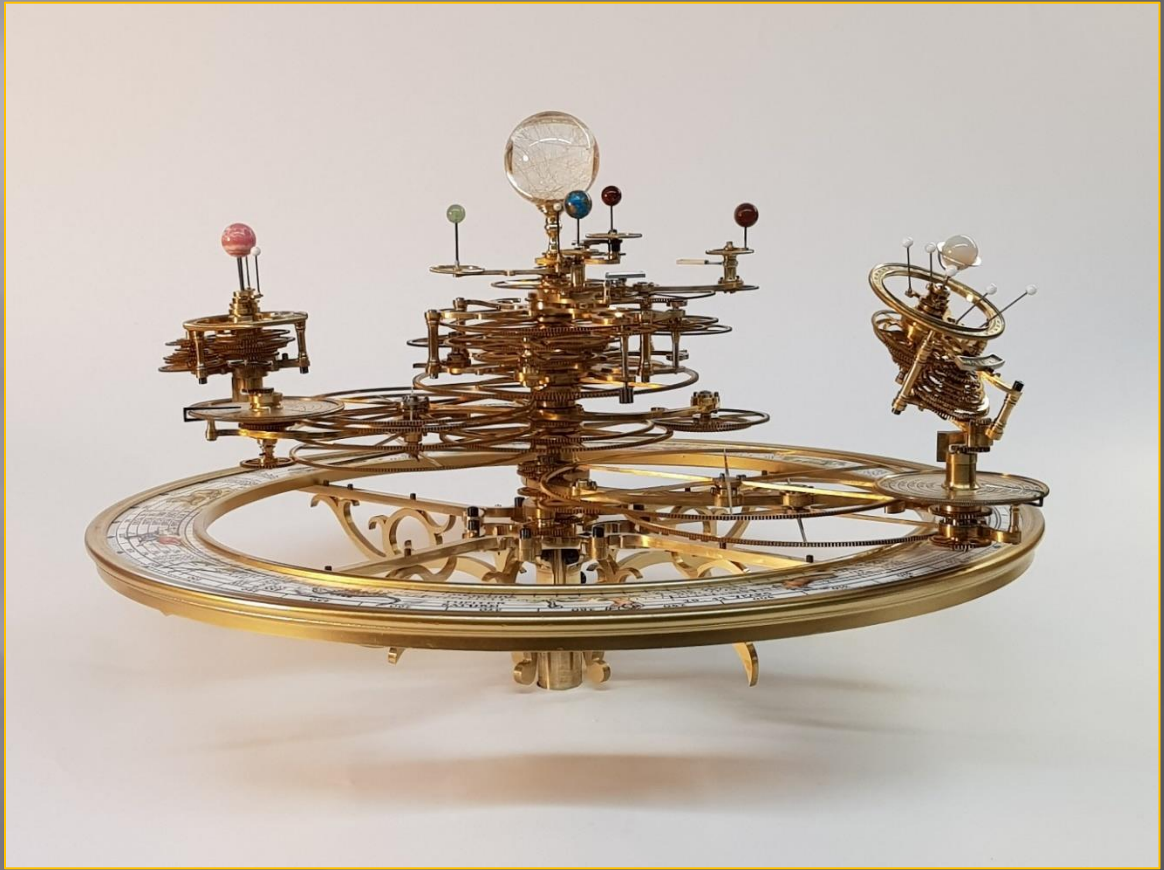




The Earth is made from turquoise with continents formed in gold leaf, auxiliary dials are French silvered.

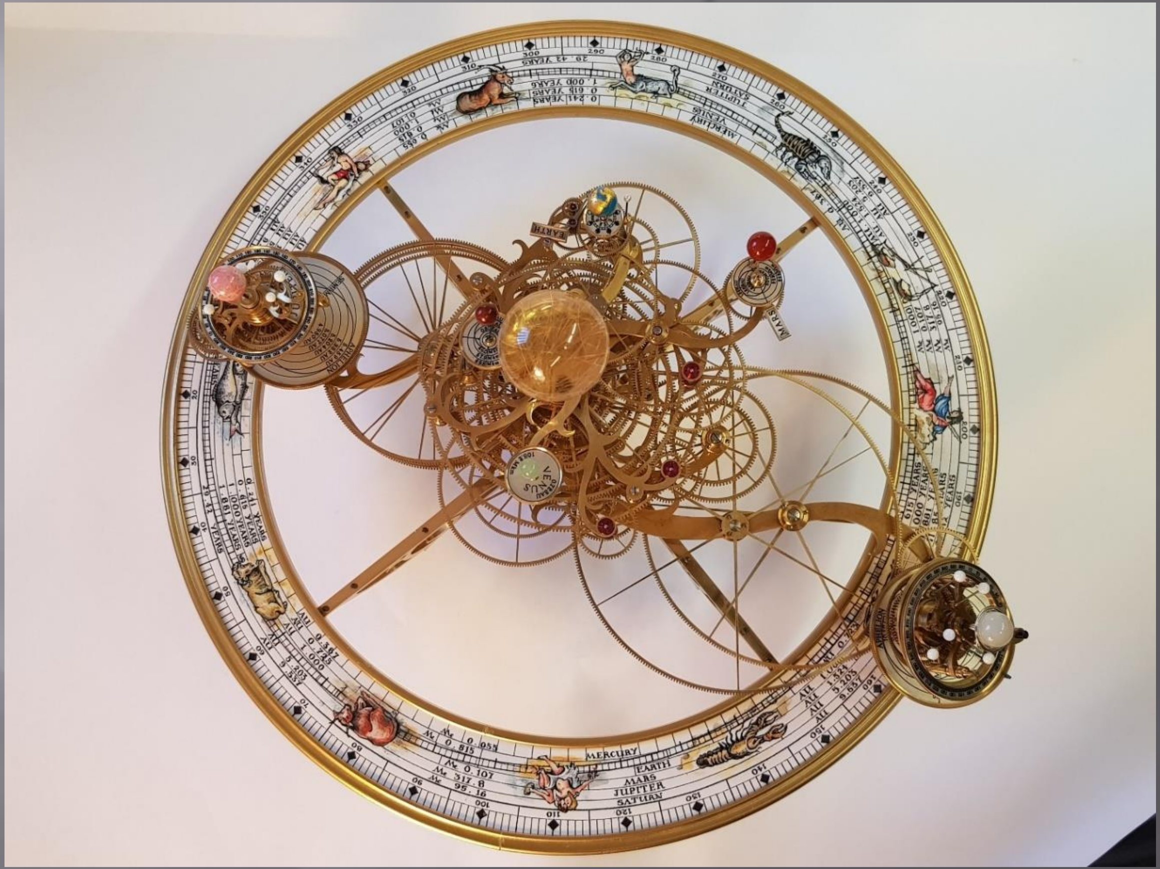
The orrery

The orrery



The orrery is the most complex module at 111 wheels and 739 parts

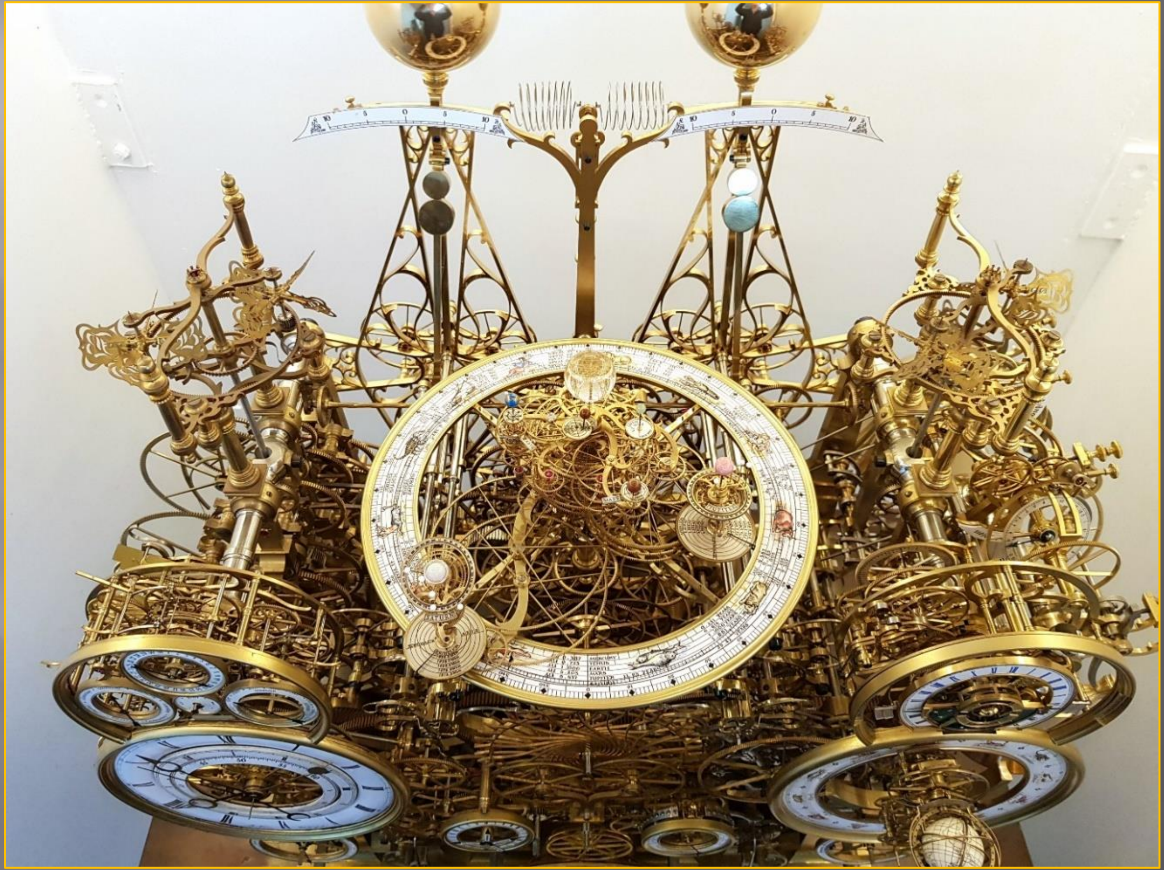
The orrery



This is an example of "Buchananization", where wheels of differing diameters are stretched to fill the space available, instead of using arms with multiple idler wheels to deliver power from the center to the planets.

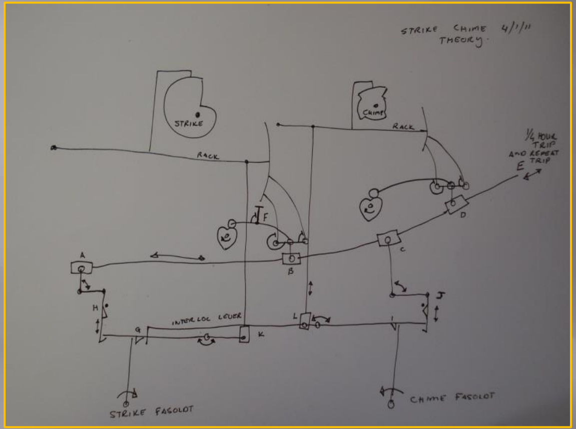
The orrery - Demonstration

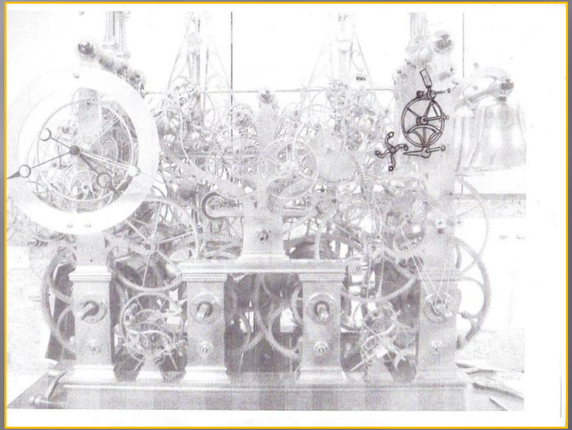
A gear-head's eye candy, orrery

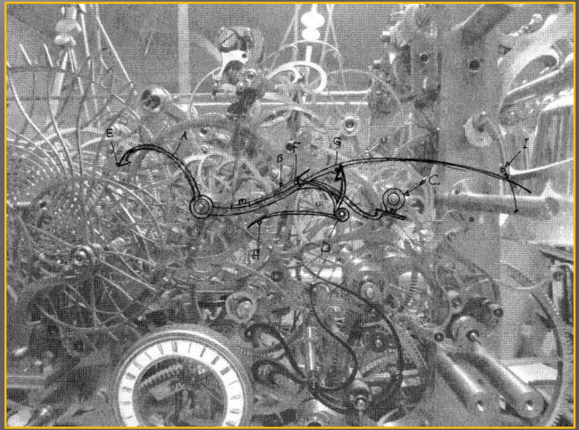


Buchanan said "If a spaghetti factory made wheels, it would look like this."

Strike train control

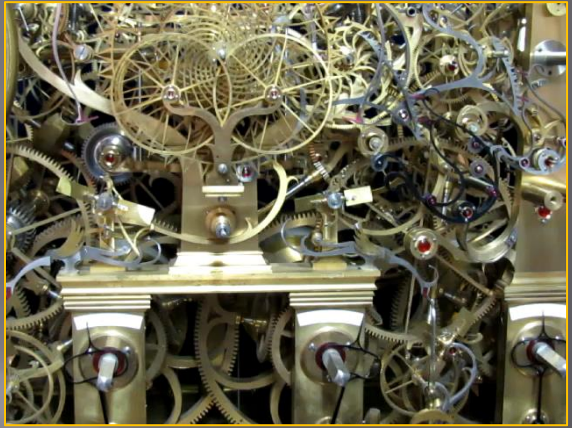


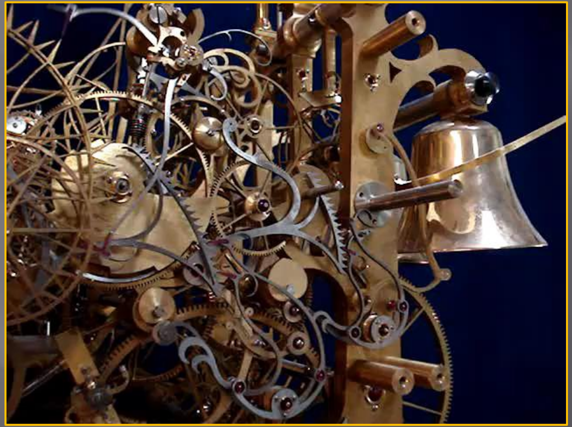




Design from concept schematic to parts design.

Strike and repeat components, levers, detents, racks, pawls

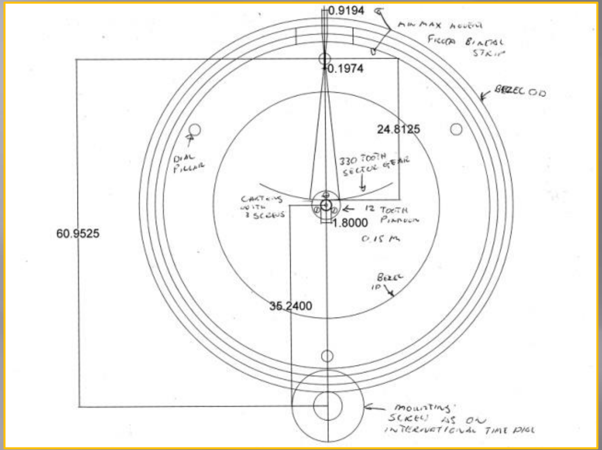


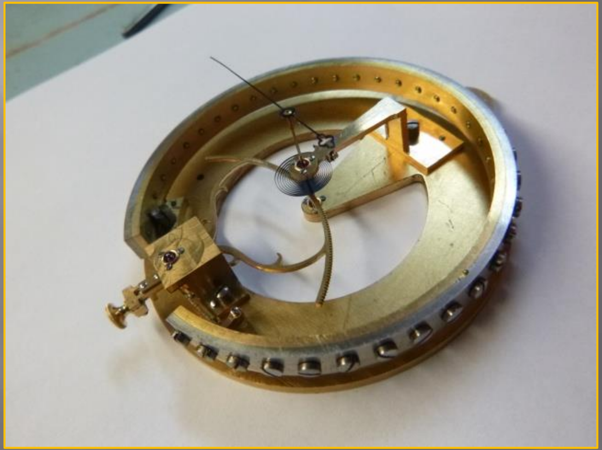


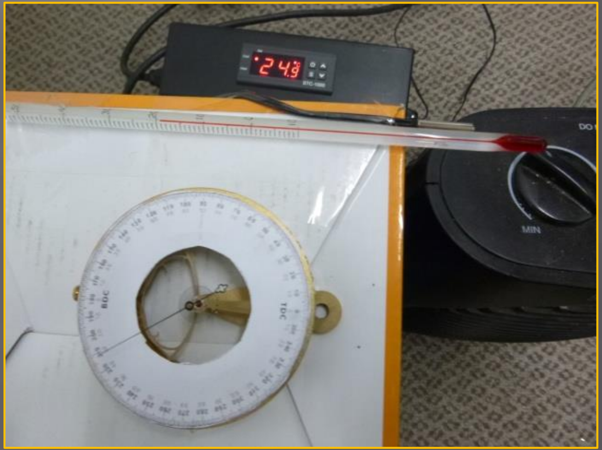
Strike repeat components, levers, detents, racks, pawls demonstration

Demonstration shows the bird analogues used to raise rack levers, control strike and escapements
The strike train will operate as a normal quarter striking clock in both petite and Grande sonnerie
in addition to having an on demand quarter pull, repeat function in Grande sonnerie.

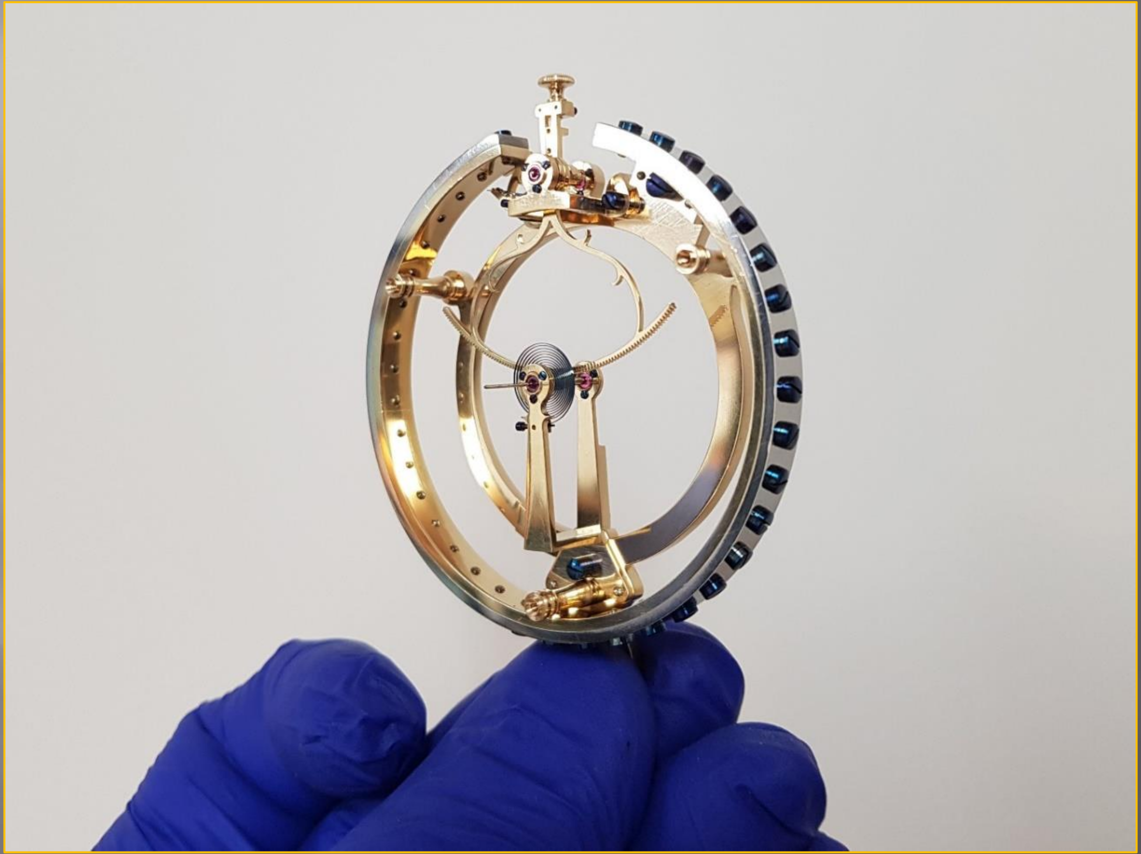
Thermometer







Thermometer



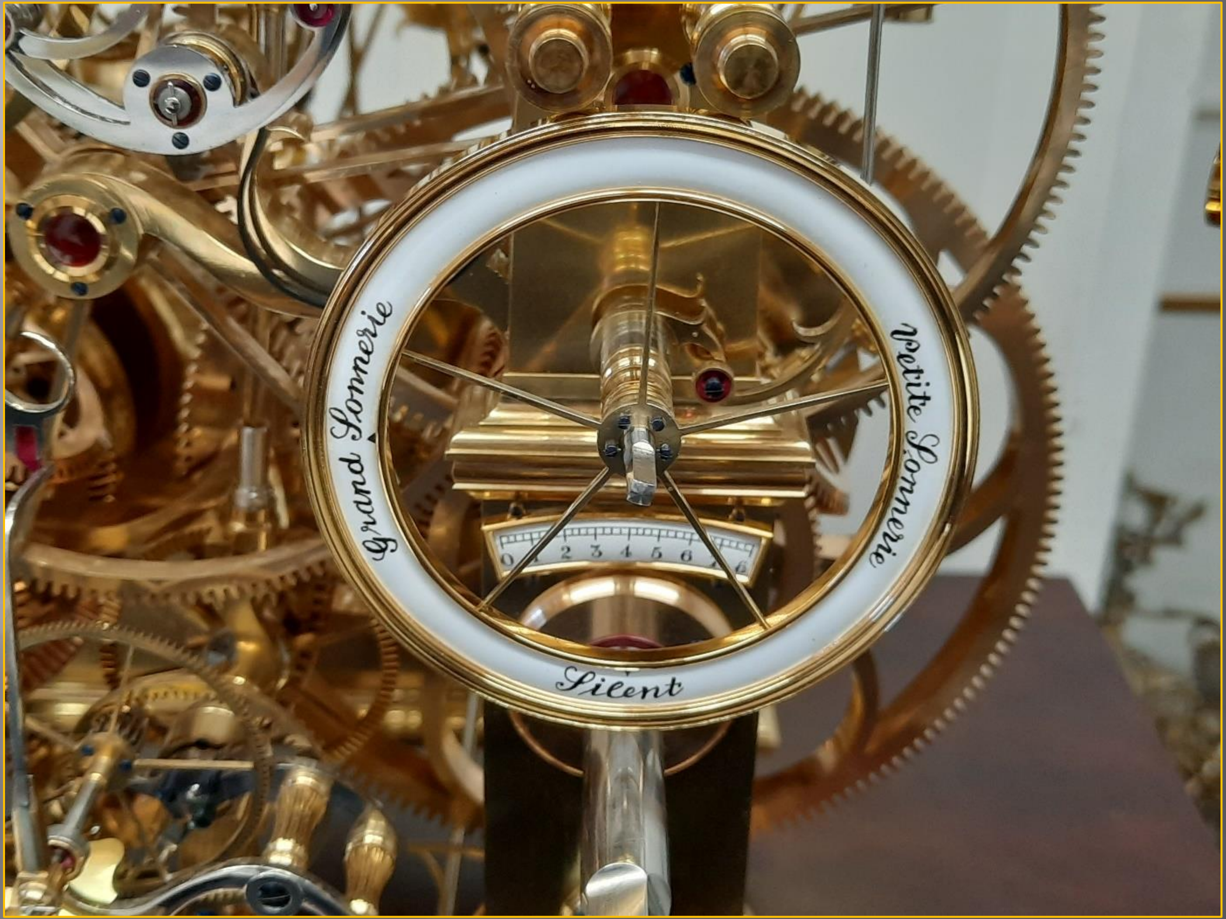
The bi-metallic strip is secured with multiple screws rather than being a fused strip

Thermometer dial

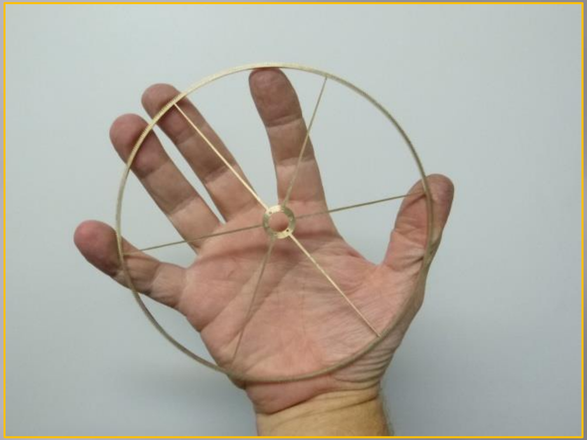
World time and demonstration dial

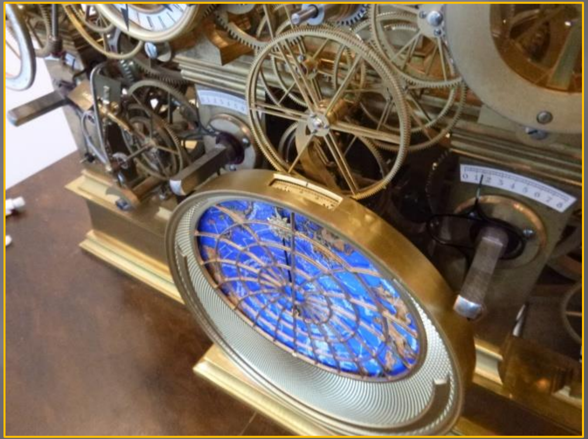
Equation of time work dial

Strike train control dial



Planisphere





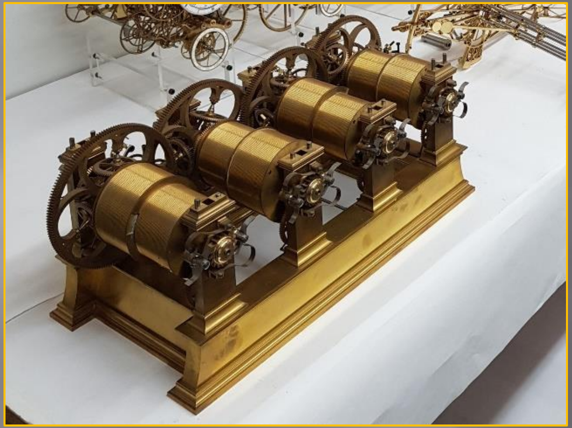
Planisphere dial

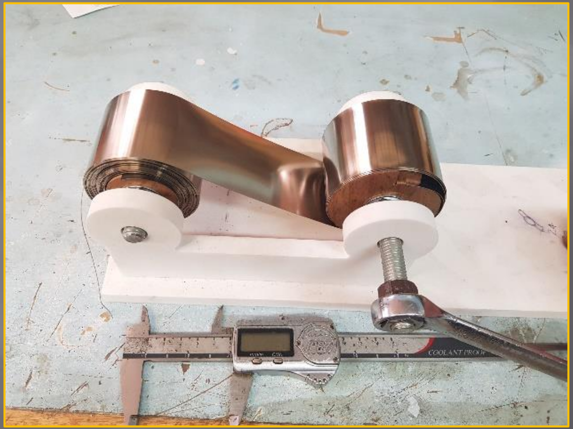
The Latin inscription around the lower perimeter of the planisphere mask is from the Roman poet Ovidius Publius from his work, *Metemorphosis*, in 8 AD:

Os homini sublime dedit caelumque videre iussit et erectos ad sidera tollere vultus.

To man God gave an upwards posture, bidding him to behold the sky, and gaze upon the stars

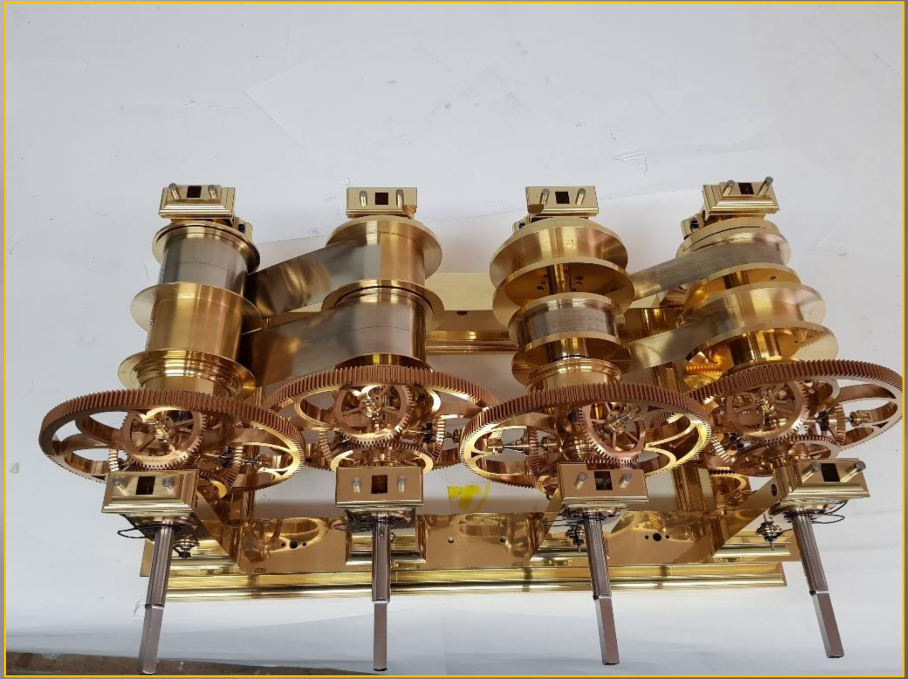
Change in design from weight to spring drive, October, 2019

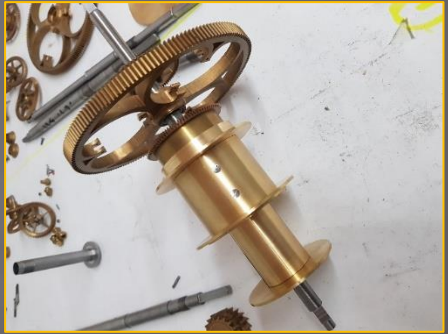


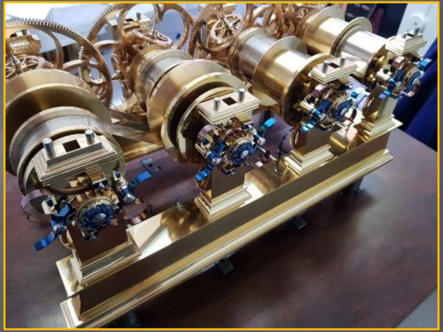


In 2003, we were unaware of motor springs, otherwise we may have originally gone with that design. This change eliminated the weight set and structural steel stand; lessening total mass from 620 to 300 lbs, 52%.

Change in design from weight to spring drive

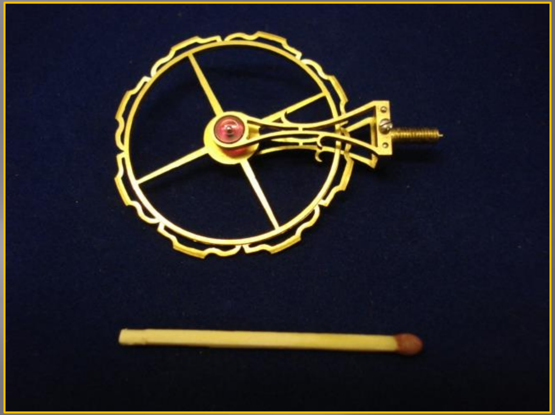






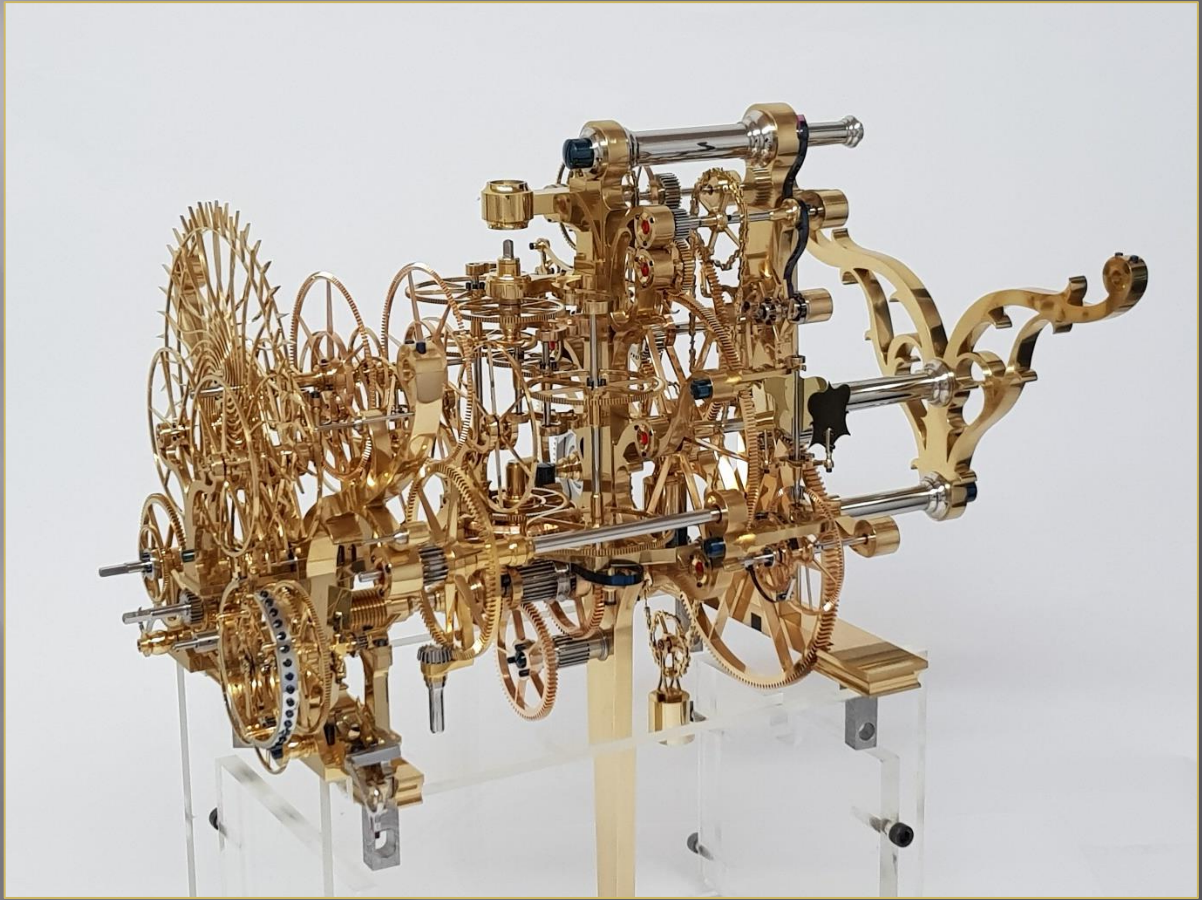
The first photo shows all the springs in the unwound position. The far left wheel set shows the front empty take up spool fixed to the arbor, with the supply spring spool to the right allowed to turn freely. Behind is the supply spool for the take up spool fixed on the arbor to the right. This spool pairing is repeated for the two strike trains to the right. Next the paired blued ratchets and decorative hub rosettes. Even tough this change was made 13 years after these were made, the spring retrofit fit perfectly.

Robin remontoire for celestial train – the pulleys and chain, 285 parts

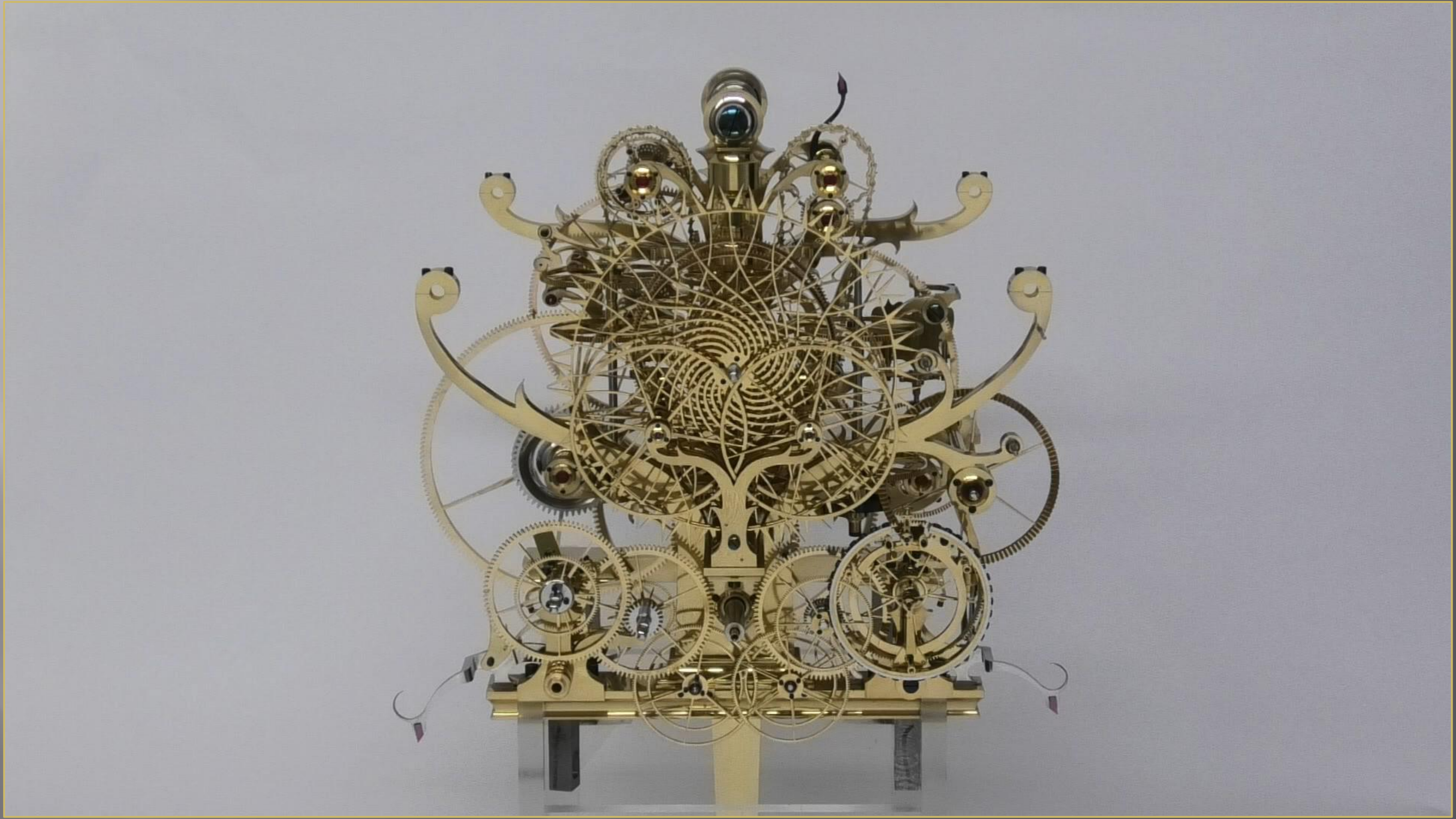


A Robin remontoire chain that matched the ivy design of the frames requires an unusual wheel pulley rim.

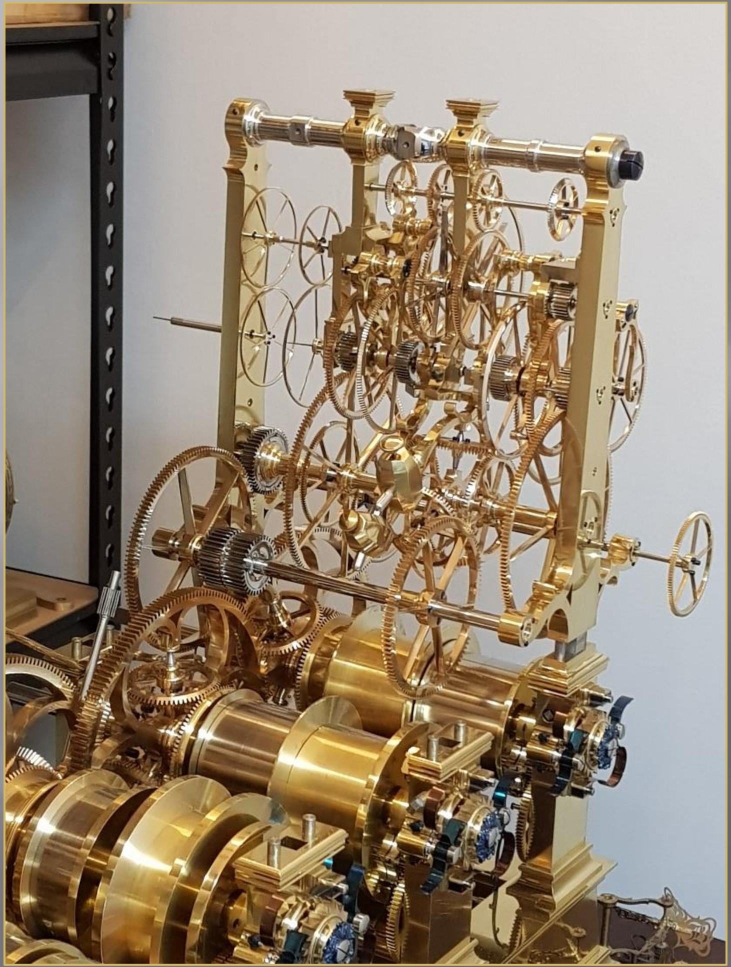
Final polishing and assembly, celestial train

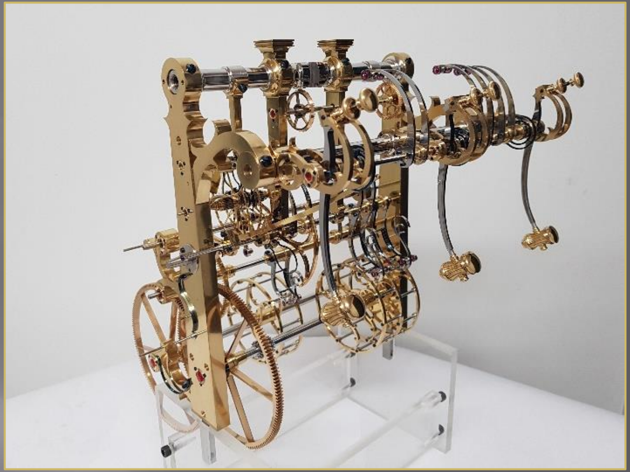


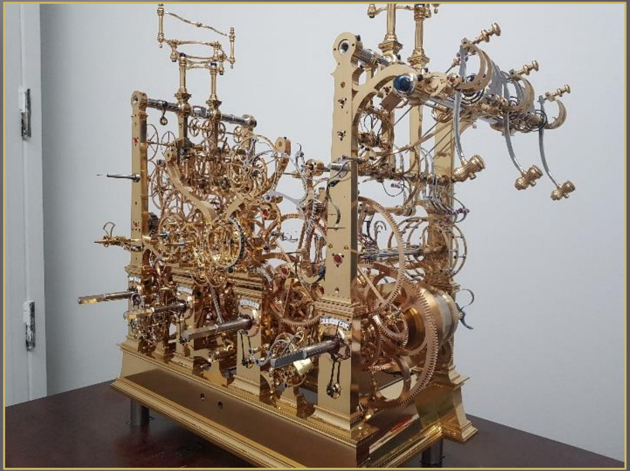
Final polishing and assembly, celestial train video



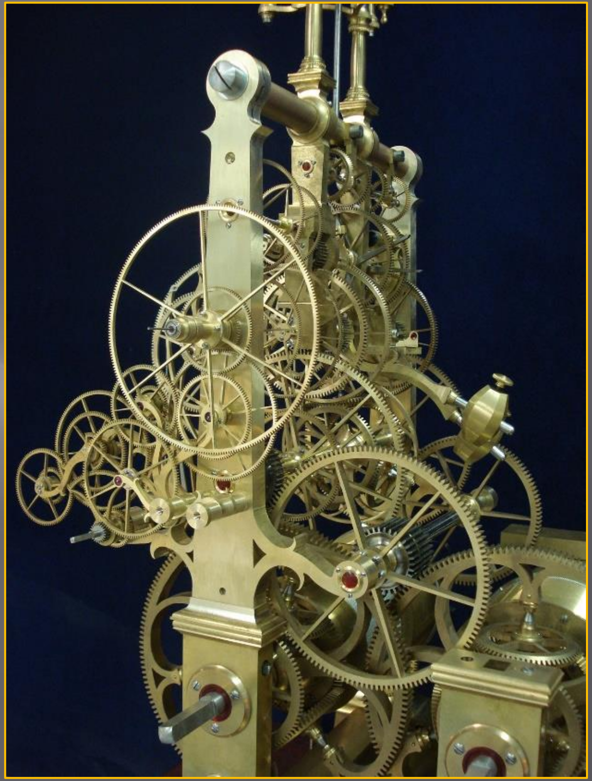
Final polishing and assembly







Frame design

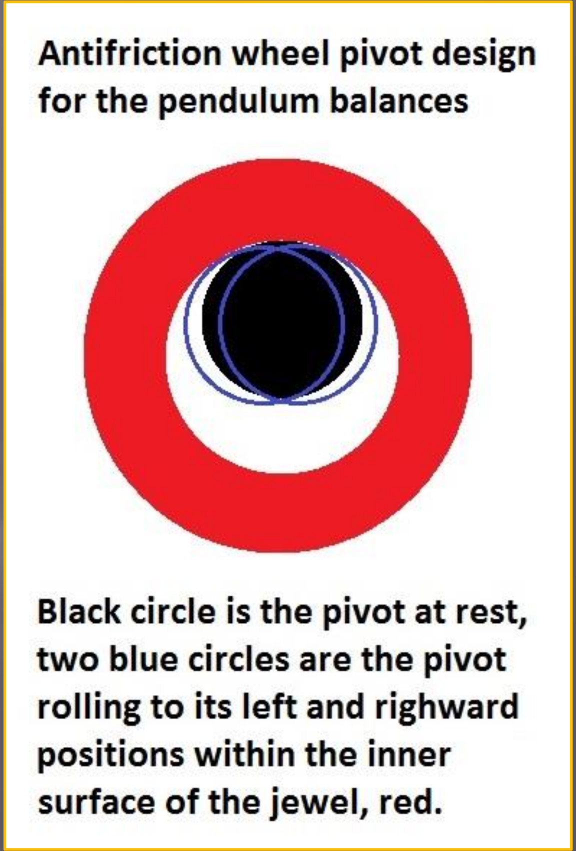


Notice the way the time train wheels seem to spill out from the sides of that train's frame; maximizing visual impact.

Final polishing and assembly

Another example of "If a spaghetti factory made wheels, it would look like this"

Balances, compound pendulums – the frames

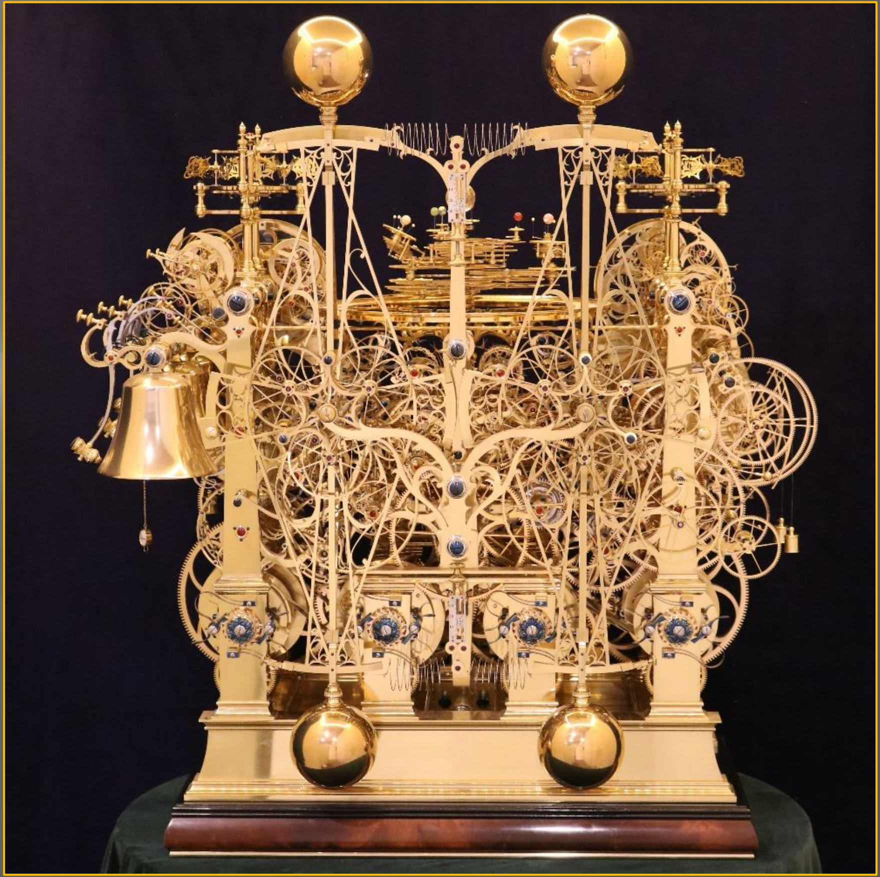


Pendulum pair, 348 parts, 12 anti-friction wheels. Diagram shows how we obtain frictionless and thus oil free reciprocal motion

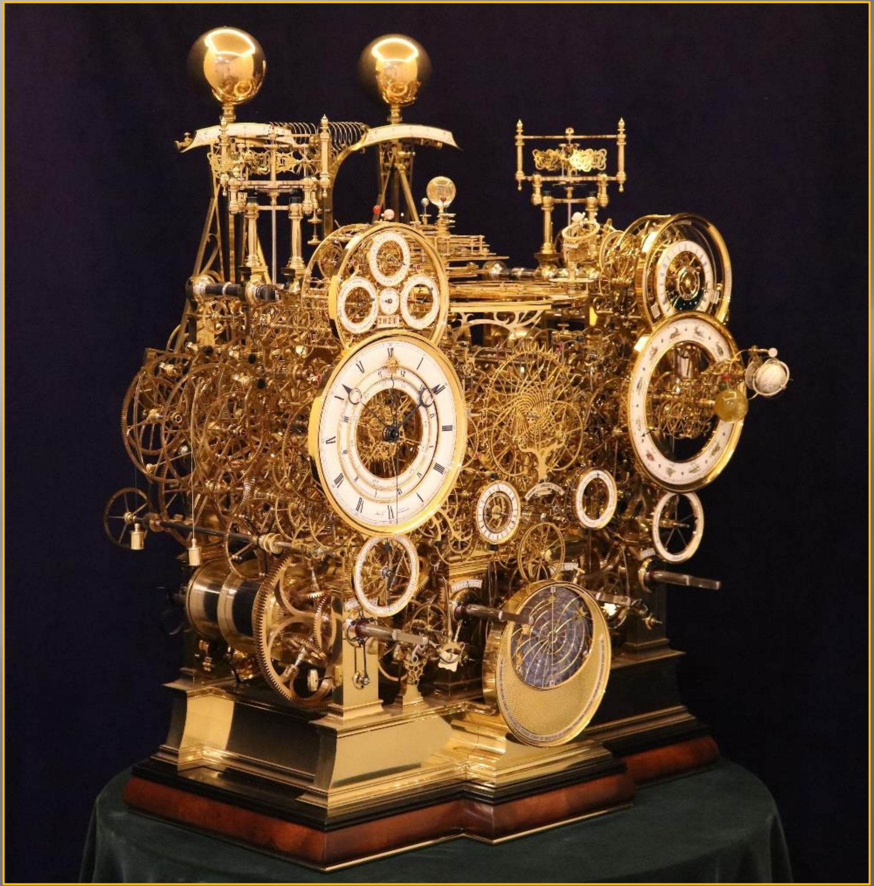
Buchanan's main tool for all flat stock

The escapement pallets illustrate the bird allegory used throughout the movement.
Next the fine polish as well as the blue, silver and red accents that will be seen throughout.

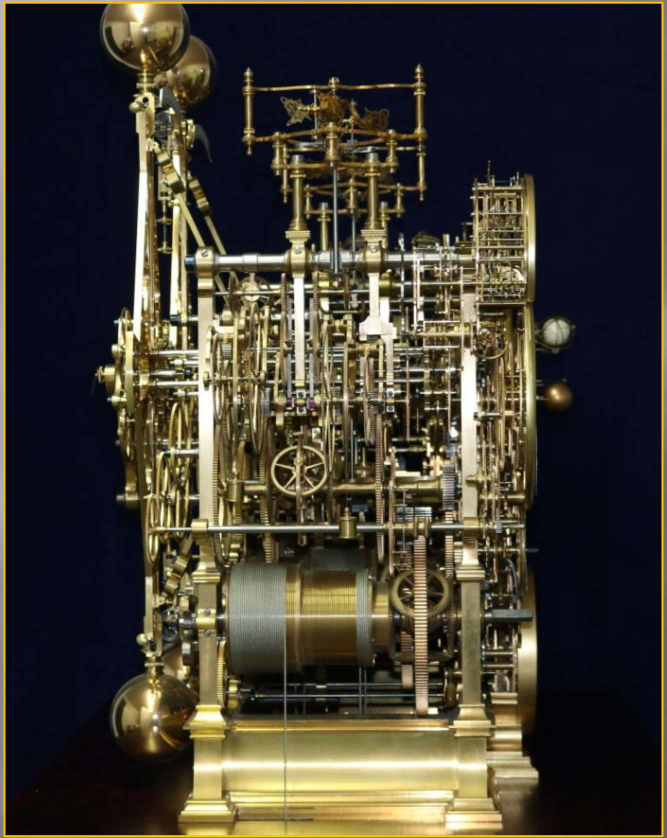
A gear-head's eye candy

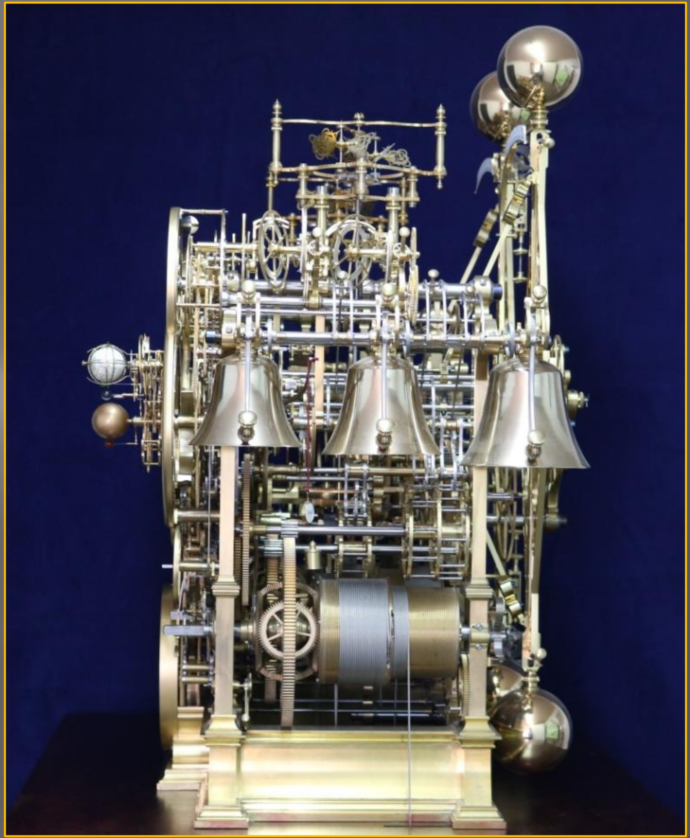


A gear-head's eye candy



A gear-head's eye candy



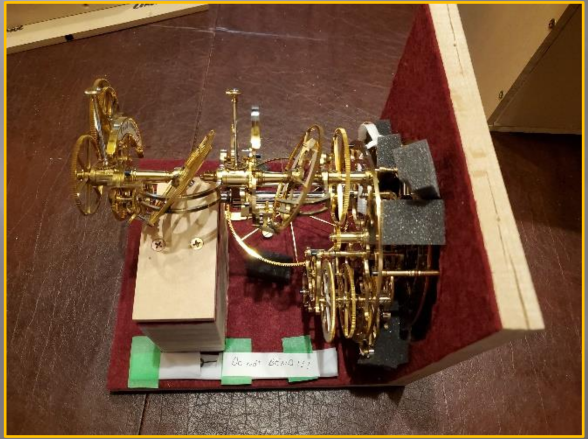


One feature of skeleton clocks I dislike is that from the side they appear to be a scarce number of bare arbors with a smattering of wheels…I think we have avoided that look here!

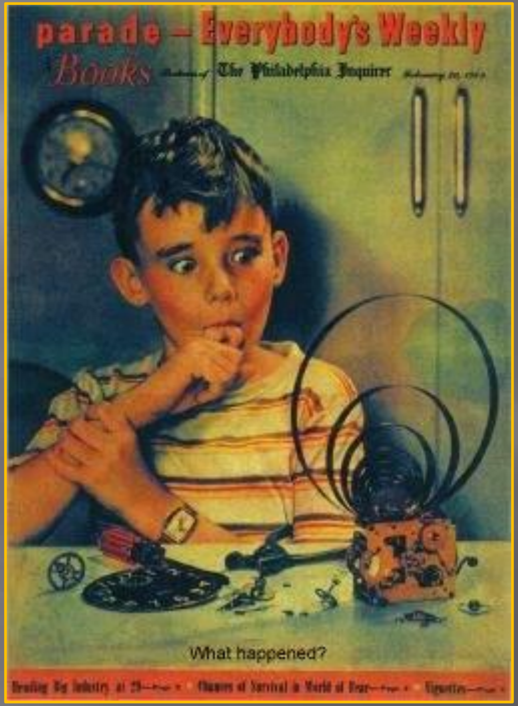
How is such a complex, delicate machine shipped and delivered?

"Threading the needle" fifth photo, was the tight 90 degree turn needed to negotiate up my narrow rear staircase. This was the most nerve racking part of the delivery.

There were 13 separate, specialized crates for the sub-assemblies



So how do I put this thing together?



Very, very carefully.

Very, very carefully. For the first couple of days I was so nervous that I had difficulty keeping my hands steady and could only work an hour or so. Eventually I gained confidence and it took just over a week to reassemble. Installing the pendulums, the Sun/Moon module and the orrery

…and now time for an adult beverage.

For more information and to follow this project on a monthly basis:
www.my-time-machines.net
The monthly construction index:
www.my-time-machines.net/astro_index.htm
YouTube channel for construction videos:
www.youtube.com/user/fgtyc
URL's for written papers on this project:
http://www.my-time-machines.net/papers_and_presentations.htm

END