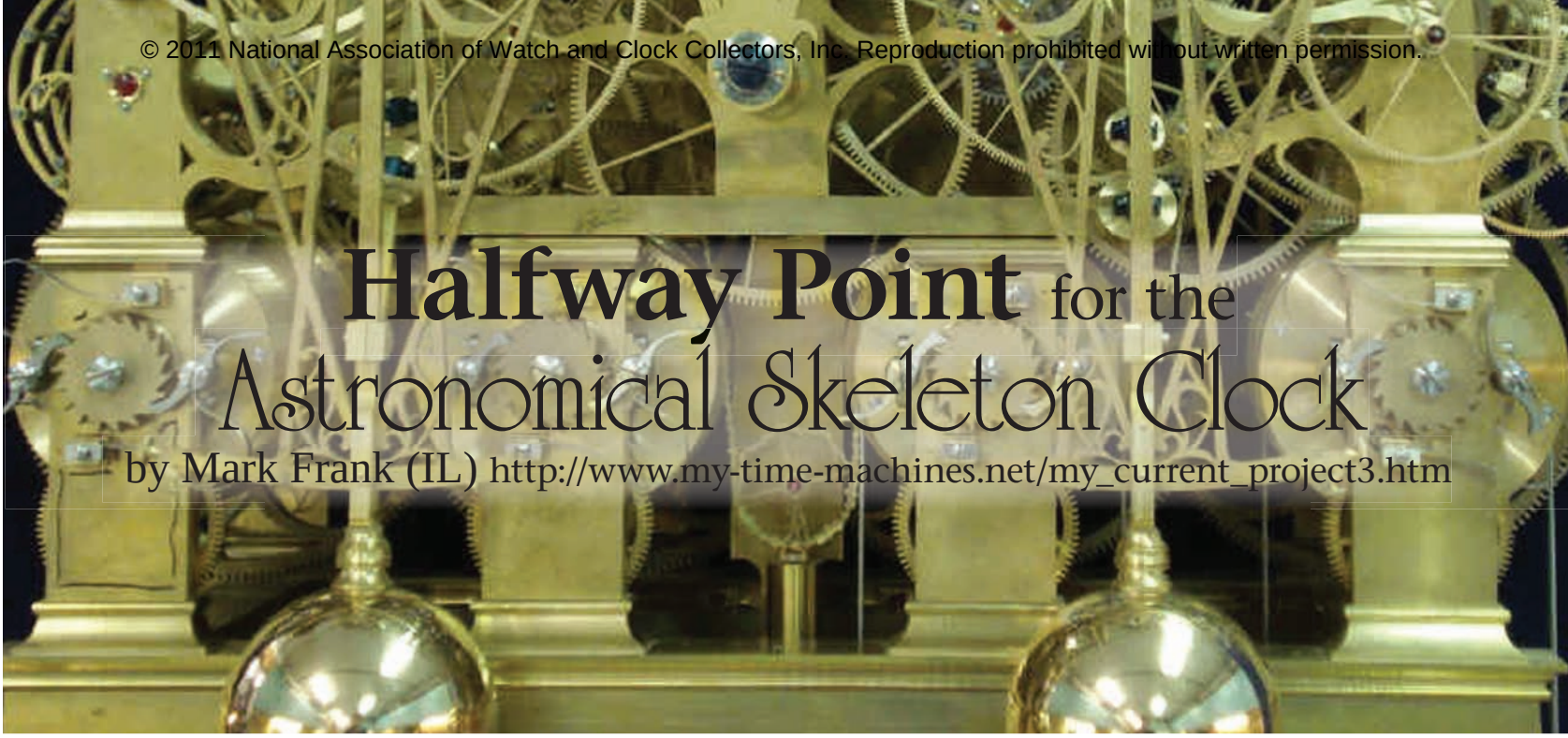

Halfway Point for the Astronomical Skeleton Clock

by Mark Frank (IL) http://www.my-time-machines.net/my_current_project3.htm

In August 2007 an article was published in the NAWCC *Bulletin* outlining an astronomical skeleton clock I designed and am having built by the specialty clock firm, Buchanan of Australia.[1] At the time there were photos of the full-scale wooden mockup and a description of the various complications based on my website paper.[2] Actual fabrication had just begun the month before.

The three guiding principles I had outlined at the beginning of this project was for the clock to have size (i.e., it must be larger than a typical domestic clock, but not so large as to be uncomfortable in a domestic setting); complexity, as demonstrated in a multiplicity of functions resulting in a large number of components; and movement. This last goal is where I believe this clock will excel beyond most others through its use of multiple remontoire, compound fly fans, and an escapement with a strong visual impact. Most other clocks, even those with many complications, except for their pendulum and escapement, are still quite static devices. This machine is designed to catch, hold, and mesmerize the viewer the moment he or she enters the room through the use of complicated movements in a variety of places and at relatively rapid intervals, combined with highly polished moving surfaces—a sort of Rube Goldberg meets John Harrison.

I knew at the time I conferred with the Buchanan firm that I had found perhaps the only person who had the skills not only to carry out my dream project but was brave enough to try! I decided right then that I would throw everything at this in terms of specifications and financing. There would be no compromises. I am privileged to be at the point where I was able to meet this gifted man and have the wherewithal to support this multiyear endeavor. When completed, we will have about 350 wheels and from 8,000 to 9,000 parts.

The project began with my conceptual drawings in October of 2003 and continued refinement through the first half of 2005 while Buchanan was working on another large project. During this time the firm had also done some initial design work for some of the various subsystems I had envisioned for the movement. The initial wooden mockup was delivered July 2006 and fabrication commenced in July 2007.

Since then steady progress has been made toward completion. As of this writing (August 2010) I can say we are at or slightly past the halfway point in the creation of this fantasy machine. It's been just over three years since metal began to be cut, and if momentum is kept, and considering our path along the learning curve of this project, we should be finished in another two to two and a half years, making this a decade-long endeavor. If one looks back in horological history and explores the time frames needed for other outstanding, complicated projects, this is not unusual.

However, unlike many of the complex clocks made in the past 200 years, this will be nearly 100 percent the creation of one man. The only exception, at this point, will be the fabrication of the porcelain dials and jeweled and roller bearing pivots. Even the final gold plating will be done by the same man who created this device. And unlike the more recent efforts in the twentieth century as exemplified by the Jens Olsen[3] and Türler[4] clocks, this project is being made more in keeping with the masters of the eighteenth century than today. There are no design-to-build set of drawings, no computer-aided design (CAS), and no computer-aided manufacturing (CAM). Freehand drawings with associated calculations are made "on the fly" as needed just prior to fabrication of a part or assembly. All the necessary information to create the device is in the builder's head and guided by the mockup, ad hoc drawings, calculations, and with my input for the overarching visual design and functionalities. The entire

Figure 1. Jeweler's saw with binoculars to cut all flat stock.

Figure 2. Original plate and spacer configuration.

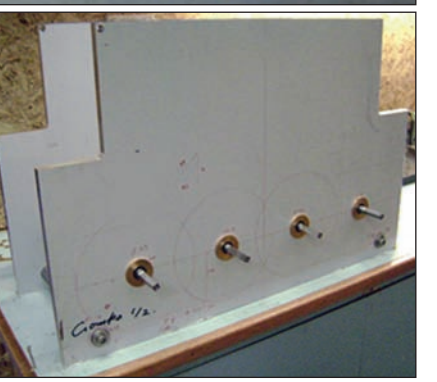

Figure 3. Opaque nature of this configuration.

flat and wheel stock is cut out by hand on a jeweler's saw equipped with a magnifying stereoscope (Figure 1). Well over 300 hundred wheels, nearly 2,000 spokes, will all be cut in this way. We have finished just over 140 wheels.

A Frame Redesign

Originally, the movement was to follow the general design of a conventional plate and spacer frame (Figures 2 and 3), with two main plates between which the movement wheels would be mounted as well as any subplates with their components. The raw brass stock for each plate was two by three feet by ½" thick and about 100 lb. each. This type of design would present many difficulties for construction because the plates were bulky and heavy. Also, until fully fretted out, they would be quite opaque, making it difficult to see and document what was going on. We immediately saw the advantages of making a temporary set of three pairs of subplates out of clear ½" clear plastic, to solve these issues. As construction progressed through 2008, the wheels, particularly those of the time train, which was the first train to be made, were filling in the plastic plates nicely (see Figure 9). I became concerned that no matter how well we fretted out the main metal plates, we would lose much of the view of the wheel works within. With the main plates being ½" thick and these frames needing to support over 350 lb. in combined movement and drive weights, there is a limit as to how fine one could fret out these plates.

In most skeleton clocks it is the frame that is paramount; just look at any Smith of Clerkenwell three-train musical exhibition clock, or the elegantly curvilinear James Condliff clocks, or the beautifully executed Arabesque double frame by Evans of Handsworth. The main show is the frame. This makes sense since most conventional clocks have three to five wheels per train, so it is difficult to make a real statement with only these few wheels to work with. The French make an exception to this with their great wheel skeleton clocks featuring all manner of artistic spoke design within a spare Y-shaped or glass-backed frame.

In this movement, the attention grabber is the number, style, and placement of the wheels as well as the frequent movements in connection with the three remontoire and their flies. So in December of 2008 I asked for a redesign of the clock based on a different frame style to more fully expose the wheel works. This was risky because we had already been fabricating parts for a year and a half based on a curvilinear approach exemplified by those main plates as well as any other non-wheel components already made (Figure 4). In March of 2009 a new mockup was produced based on a pillar frame. Fortunately, this fit quite well with what was already done and in the opinion of most people who have compared the two designs is an improvement.

This change has many advantages in addition to allowing more exposure of the movement. It allows for a modular design, with each train being independent from the others for purposes of fabrication, assembly/disassembly (Figure 5). In reality, there are some overlapping functions between the modules, but this in no way diminishes the serviceability of the design. We are creating this movement with an eye toward its future maintenance. If, after 30 years or so the movement needs service that couldn't be done, then it would run the risk of it falling into disrepair and, perhaps ultimately, ruin. To this end, the four corner pillars are also separable just above the main train weight barrel pivots; this allows one to service the upper trains without having to deal with the heavy barrel and base frame components. The four lower center pillars support the upper interior subplates containing the celestial train remontoire, the time train escapement and support for the orrery superstructure. These plates can be removed as a unit. With this minimalist frame we have also created in the words of the builder, "a spider's web holding a haze of wheels." One negative aspect

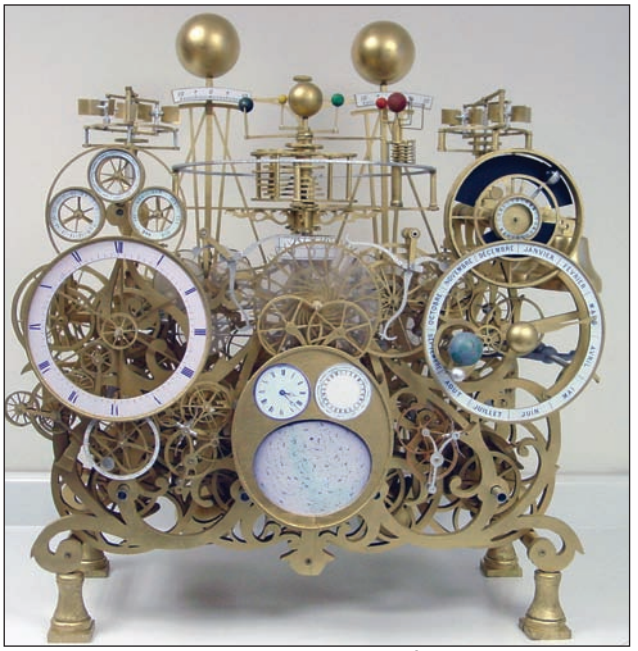

Figure 4. Original plate and spacer frame design, mockup.

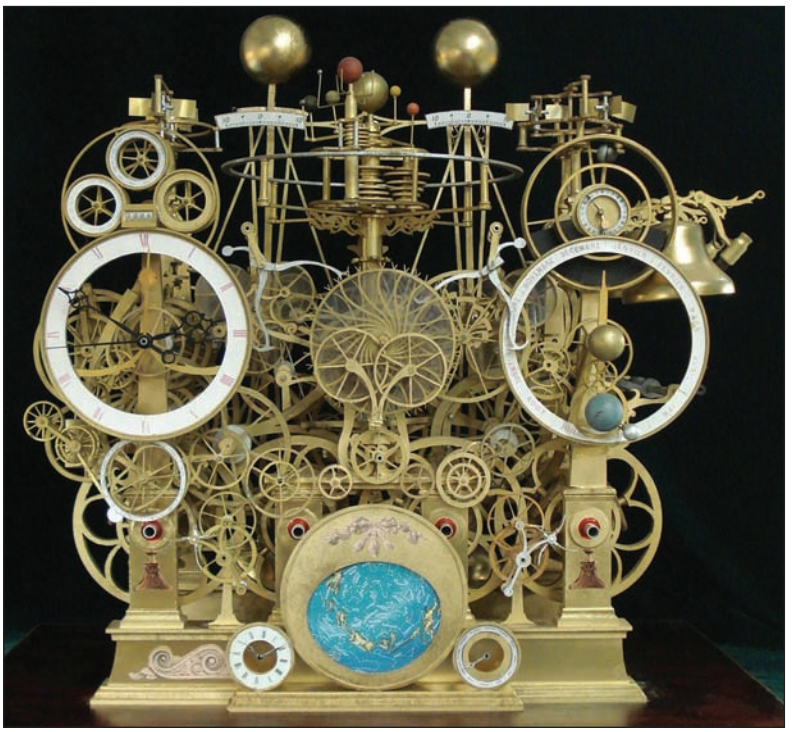

Figure 5. Revised pillar frame design mockup.

to this design is that placement of the wheels is far more restricted; we no longer have a blank canvas in the form of a vast plate from which to choose their locations.

Roller & Jeweled Bearings

In the original design specifications I had all but the weight barrels running in jeweled pivots with the former in sealed roller bearings due to the stress put upon these areas. Later, this was changed so that all of the long arbors that spanned completely between the front and back pillars, about 13", would also be in roller bearings. Such long, heavy shafts present the risk of cracking the jeweled pivots during the many disassembly operations. We also determined that in addition to those components already equipped with roller bearings, all wheels that would turn faster than once per hour would also use them. The two exceptions are the remontoire and strike fly fan assemblies because these areas command special visual attention and real, oiled jewel bearings would show best. Those components are located in easily serviceable areas. All of the rest of the wheels, which will turn less than once per hour, approximately 250 or so, will run in dry, jeweled bearings. Breguet is quoted as saying "Give me the perfect oil and I will give you the perfect watch" referring to the trouble with deterioration and dirt accumulation associated with oil; if it can safely be eliminated altogether so much the better. Also employed is an escapement based on Harrison's grasshopper design—one which also sidesteps the need for oil. We are using hard tool steel for the pivots, which are in turn embedded into the stainless steel arbors. I will readily admit that we are exploring some new territory here, and there is some controversy as to the wisdom of this arrangement. I am

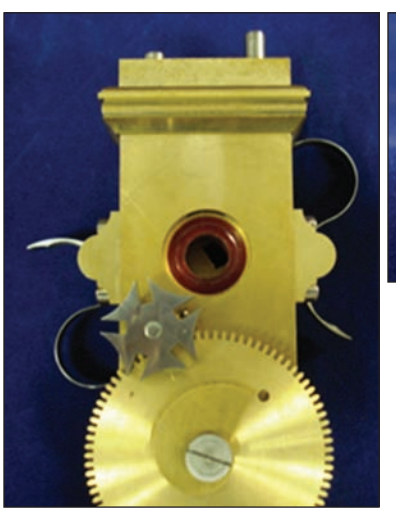

Figure 6, left. Red plastic ring hides roller bearing pivot.

Figure 7, above. Typical jeweled bearings in decorative chatons.

confident that we have struck the right balance in the design of the various wheel pivots, which will result in a machine that, considering its great complexity, will run as trouble-free for as long as can be reasonably expected before servicing. Wherever we have roller bearings there are custom-made red plastic rings and caps made from UV-resistant automotive taillight plastic to hide the bearings (Figure 6) and match the color of the actual jeweled pivots (Figure 7).

The Time Train

Several novel designs are used in the time train. First is the dual Bernard-Henri Wagner-type remontoire driven from a common differential and powering a pair of independent, counterrotating grasshopper escape wheels (see Figures 14 and 29). The other is the compound pirouette flies for the remontoire (see Figure 10) and the epicyclical maintaining power for all four trains which use wheels in two dimensions rather than the usual single plane (see

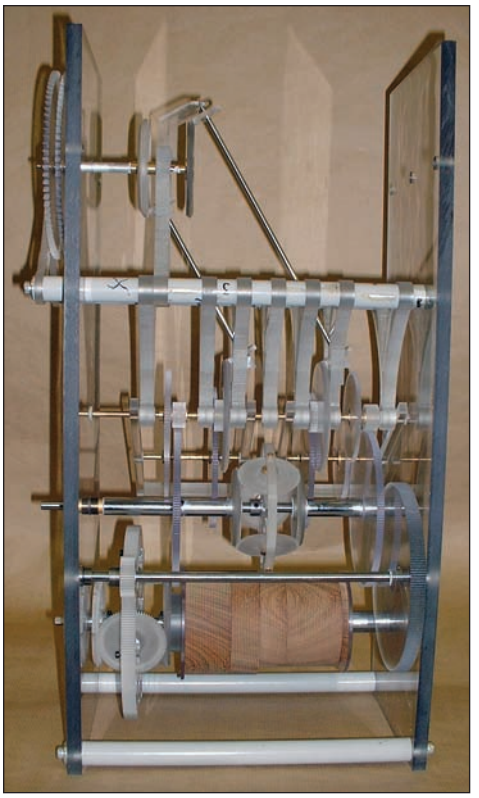

Figure 8. Plastic working mockup of time train.

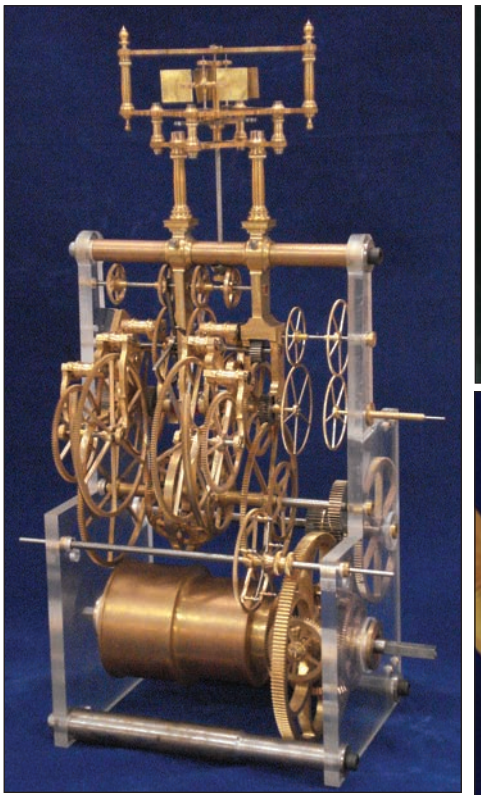

Figure 9. Completed time train between temporary plastic plates.

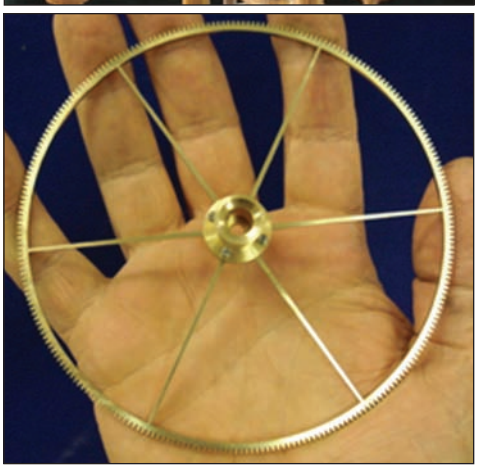

Figure 10, top. Completed fly with pierced blades, columns, and finials.

Figure 11, above. Typical "feather-light" wheel style.

Figure 24). Before construction could begin, working models of these components were created from plastic to test our designs. Indeed, a model of the entire time train was made all the way through to the dual balances. From this model we were also able to not only test the practicability of the train but also to redesign and refine how the components within were arranged and mounted relative to each other to achieve the most pleasing visual presentation. In one example we had a row of six drop-down frames to hold the dual remontoire, making this system look a bit cluttered (Figure 8). We were later able to reduce this to two (Figure 9).

The sequence of fabrication began from the winding barrels. In addition to the three trains one would expect from a quarter-chiming clock, a fourth train is used to drive the 16 astronomical functions.[5] Afterward, the first clear plastic subframe was made to house the build-out of the time train. The maker's signature wheel style is to cut as delicately as possible with thin spokes and rims (Figure 11). This not only looks elegant but also shaves mass from the movement, increasing efficiency and lessening friction. In a machine of this size and complexity, friction and mass are our constant enemies.

The Grasshopper Escapement

By September of 2008 the time train, except for the pendulum balances and grasshopper pallets, was largely complete. Total parts count for the time train: 483 plus 60 wheels; for the pair of remontoire flies: 330 plus 2 wheels (Figures 9 and 10).

By the end of the year the balances were complete: 432 additional parts plus 12 antifriction wheels. Each frame is cut from one piece of ¼" stock, 23", in length and takes two weeks to pierce in the jeweler's saw. The design is first drawn on contact paper, which is then attached to the brass plate and then carefully cut (Figure 12). There can be no errors, or the entire part must be scrapped (Figure 13).

The two grasshopper escape wheels have a special swirled spoke pattern so that as they rotate past each other in opposite directions, one will see a kaleidoscopic effect. These ride in a set of eight antifriction wheels (Figure 14). The grasshopper escape pallets were purposefully made in a fanciful way so that when operational each resembles a pair of birds, complete with jeweled beaks, head with a comb, and a flourish of tail feathers in brass and steel "pecking" at the escape wheel teeth (Figure 15). All of the flat jeweling is made in-house. There are 220 parts plus 18 wheels for entire grasshopper escapement assembly (less balances).

By January of 2009 the grasshopper pallets and all other components necessary to complete the time train were finished. The clock was set running for the first time under its own power at 2:30 a.m. on the 15th; it was alive! The two second swing, at half the speed of Harrison's original H1, was hypnotic.

Setbacks

Our success, however, was short-lived. Problems arose with the grasshoppers; too much power was being

Figure 12. Brass blank with paper design template.

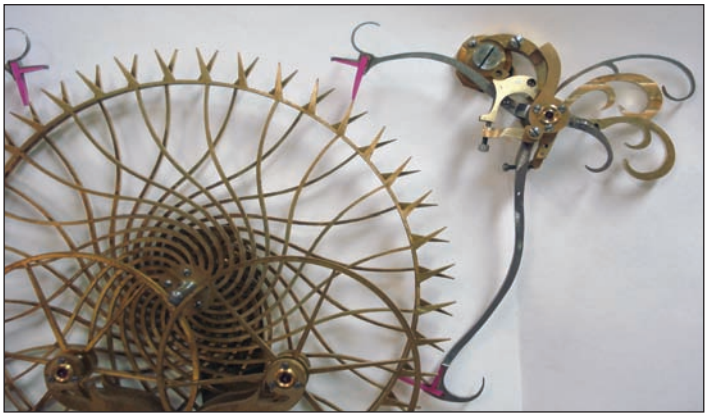

Figure 15. Fanciful escape pallets designed to look like birds.

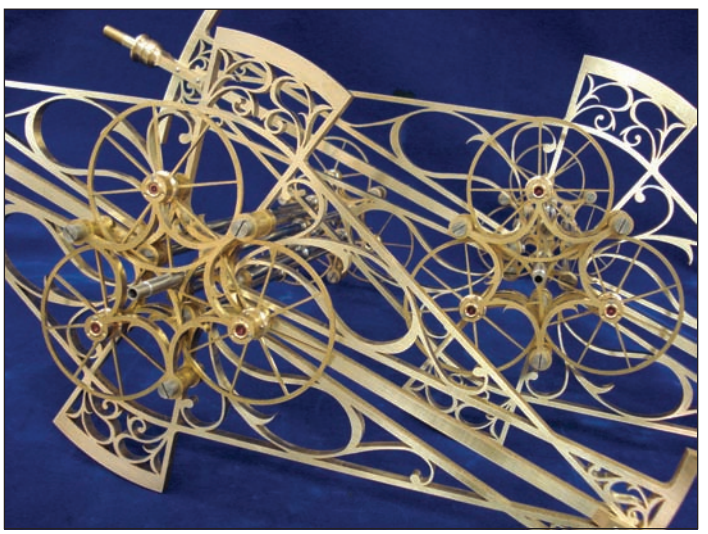

Figure 13. Completed balances, approximately 23'' long.

Figure 16, above. One of the two time train Wagner remontoire.

Figure 17, right. Robin remontoire that will control the celestial train.

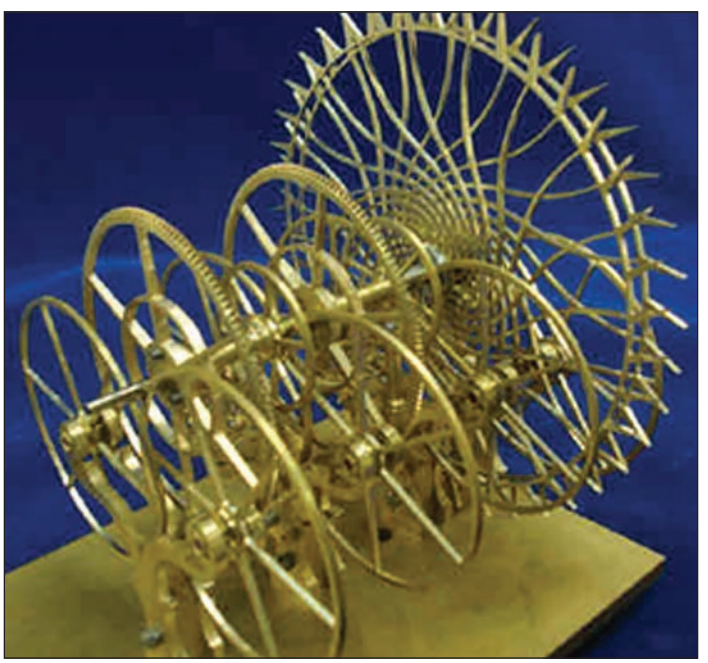

Figure 14. Escape wheels rotate on an antifriction wheel set.

consumed and tripping was a problem. These had to be completely redesigned and the current components scrapped— a month of work lost! Throughout the rest of the year further refinements were made on the operational characteristics of the time train. The cocks, bridges, mounts, the remontoire swing cages, and fly fan blades and their cages were now ready for their final decorative curvilinear shaping and fretting out, all of which is laborious and time-consuming (Figure 16). In addition, another major subsystem was also completed, the Robin remontoire, which mediates the release of the celestial train at 186 parts, 11 wheels (Figure 17). Another setback was experienced in connection with the detent mechanism controlling this remontoire—more time lost. The chain requiring 255 additional parts was a custom design with miniature ivy

Figure 18. Intricate Robin chain and pulley profile.

Figure 19, top. Frame and molding detail fabricated in wood model.

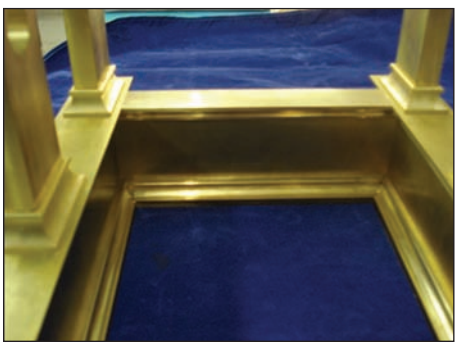

Figure 20, above. Raw frame stock assembled before final machining.

Figure 21, top. Decorative molding and sloping side base wall.

Figure 22, above center. Molding on inside upper and lower base lips.

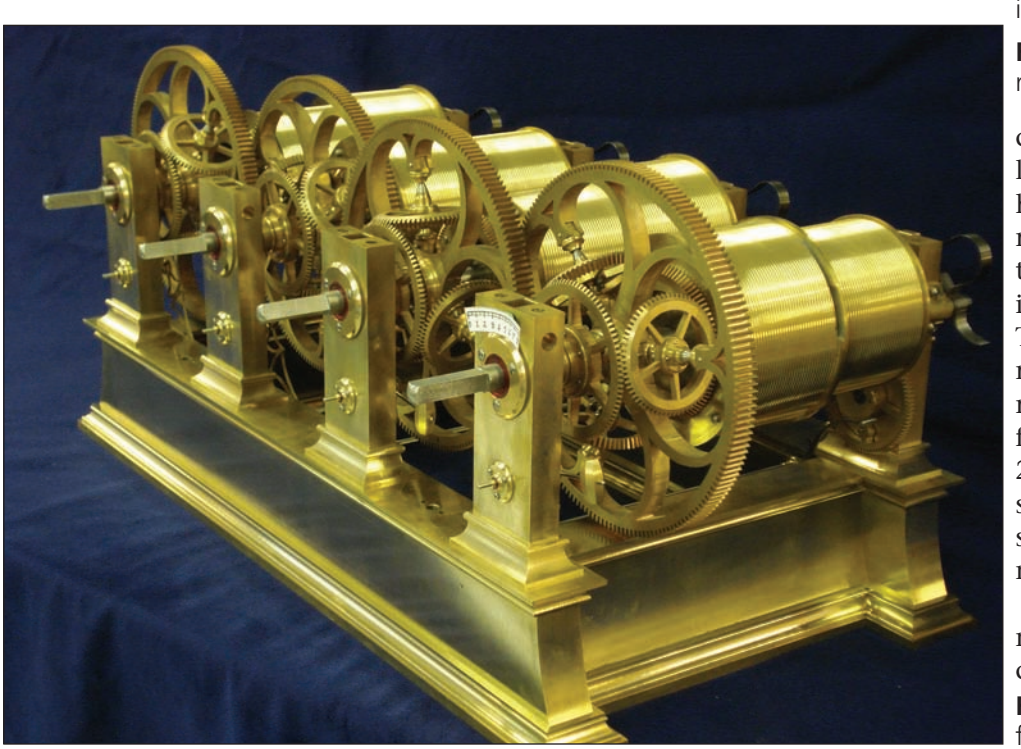

Figure 23, above. Intricate crowns requiring multiple machining steps.

spurs for each link in keeping with our curvilinear/ivy motif for the movement. These links required an intricate pulley wheel rim design. The pulley support is carefully decorated and jeweled (Figure 18).

The Main Frame

With the Robin remontoire and time train largely complete and some lower wheels for the other three trains finished, work began in September on the mainframe components, beginning with the base and lower pillar members. The lower frame and its molding details were first created and refined through several iterations in wood (Figure 19). Once the look was satisfactory, fabrication of the metal stock began (Figure 20). These were completed by December. The long frame members were first heat treated in a special-built furnace to prevent warping under the milling process. Notice the intricate frame molding work. These required custom fly cutters made by the fabricator as well as matching female cutter profiles for the inside corner work (Figure 21). Even the interior lower rails, something that one would rarely see without difficulty, have decorative molding work (Figure 22).

The crowns of the lower pillars require five separate steps and fly cutters. As finished as these frame

Figure 24, left. Completed lower frame containing winding barrels.

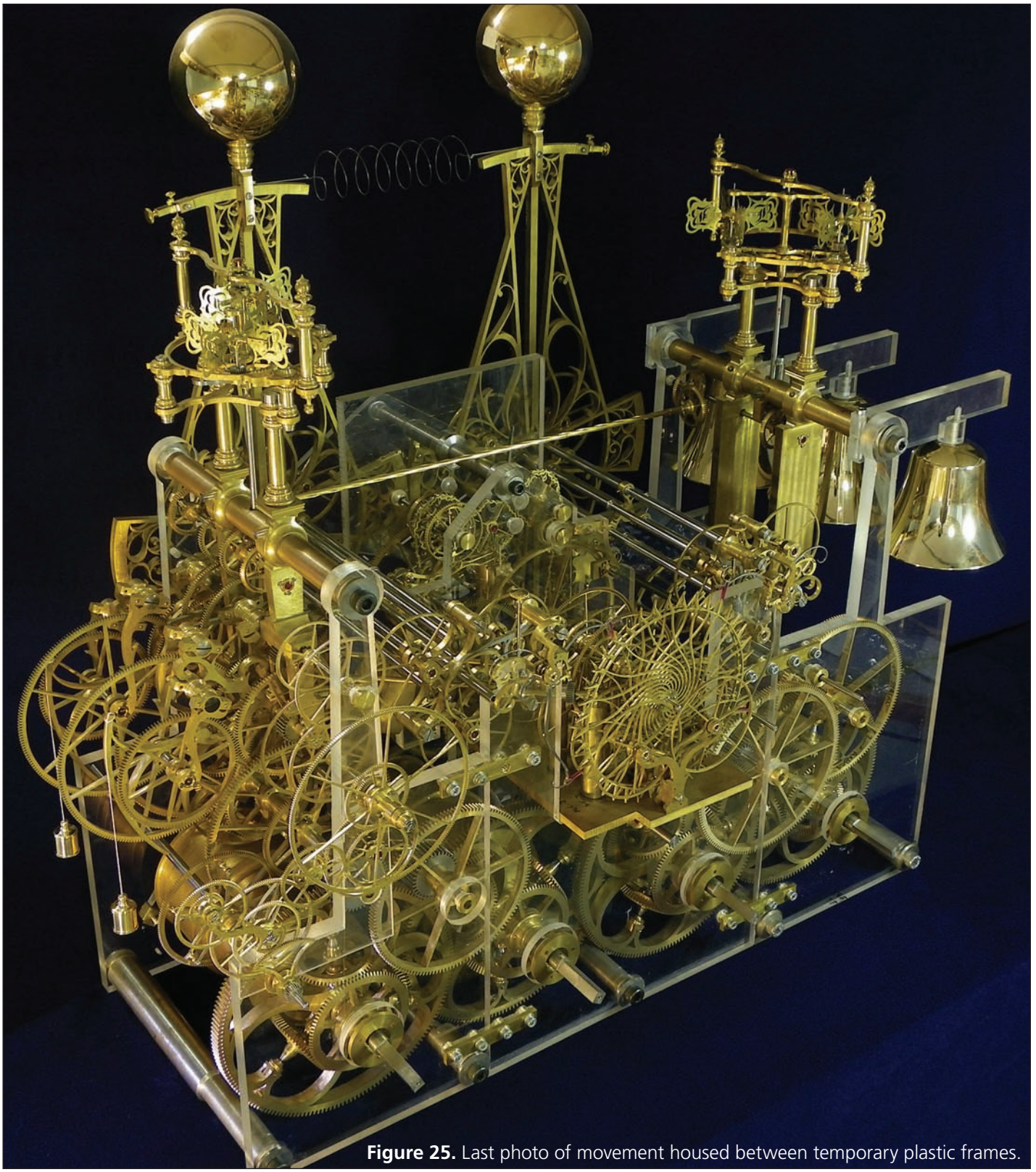

Figure 25. Last photo of movement housed between temporary plastic frames.

members look, there are still several final embellishments yet to be made to the corners of the pillars as well as the polishing and gold plating yet to take place (Figure 23). Figure 24 shows the completed lower movement and frame. The base measures 23" wide by 14" deep.

In December the project was carefully photographed for the front and rear cover shots of the January 2010 *Horological Journal*. This photo was one of the last to be made with the movement between the temporary plastic frames. It contains the entire working time train, escapement, celestial train Robin remontoire, and parts of the two strike trains. While this photo may look like a large proportion of the movement is complete, it is still lacking nearly all of the 16 celestial functions comprising again as many components as those already completed (Figure 25).

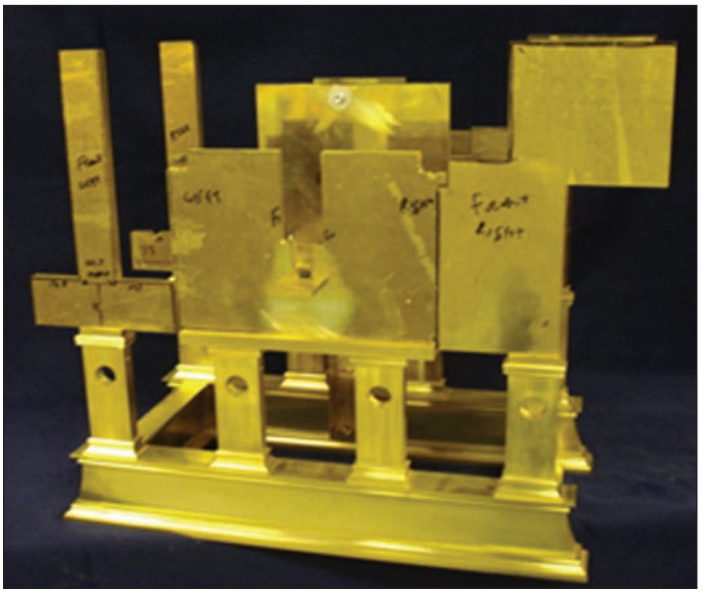

Figure 26. Rough corner and central plates.

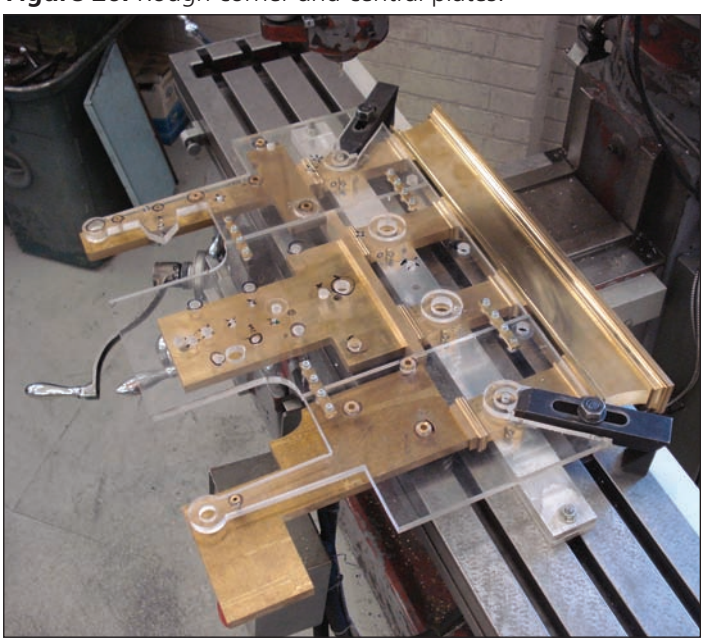

Figure 27. Original plastic frame used as template prep for drilling.

Figure 28. Equation of time differential drive (kidney not shown).

January 2010 began with the design and fabrication of the upper frame components. This was to be far more involved than those of the lower frames, which only had to contain the four main wheels. Now all of the many wheels, pillars, cocks, and bridges that have up to this point been between the temporary plastic frames had to be transferred to the new rough metal frame plates. There are four corner plates and a complex center subplate fitting between the corner plates that will contain the escapement, Robin remontoire, orrery, and pendulum supports (Figure 26). The transference began in April with the careful disassembly of the plastic plate sections. Since the clock was fully functional up to this point, these plates served as templates for drilling the metal plates. A special jig was made to mount these to a mill which was equipped with a digital plotter, the closest we come to digital machinery here. Each hole center is measured from the temporary bushing left mounted in the plastic. Afterward, the measurements are double checked against the plastic plates before drilling begins (Figure 27).

Concurrently, the equation of time drive (Figure 28) and the reserve power indicators were being made as well as other refinements such as the dishing of the entire medium to large pinions and the refinement of the decorative collets. Then further machining of various parts added definition and reduced mass (e.g., the differential drive that will run the Wagner remontoire for the dual escapements) (see Figure 29).

By July the upper plates began to take on their organic ivy shape. Remember that each plate is ½" thick and is being cut on the small jeweler's saw seen in Figure 1. Many dozens of blades were destroyed during this process. The branches will be gradually thinned out as they rise toward the top, just like in a live plant. The areas that contain the arbor's chatons will remain at ½" since the wheel arbor lengths have all been made. This however is a bonus as these will be the "red fruit" in the form of the jeweled chatons hanging from the branch ends (Figure 30). All of the screws also will be polished and heated to an electric blue color. These two color combinations, in addition to the silver stainless steel of the arbors and the rose color of the bronze wheels against the gold background of the frames, should provide a stunning display. See how the time train wheels literally spill out of corner pillars, allowing for maximal visual impact—a vast improvement compared to what a conventional plate would have offered (lower right figure, back cover).

Tracking the Process

The two top and left-side photos on the back cover show the most recent progress, as of January 2011 and just prior to submission of this article. We began this project with the four main wheels and then the time train. That train has been running on and off for well over a year. All of the wheel works that reside between the main pillar plates are complete. Now begins the many celestial

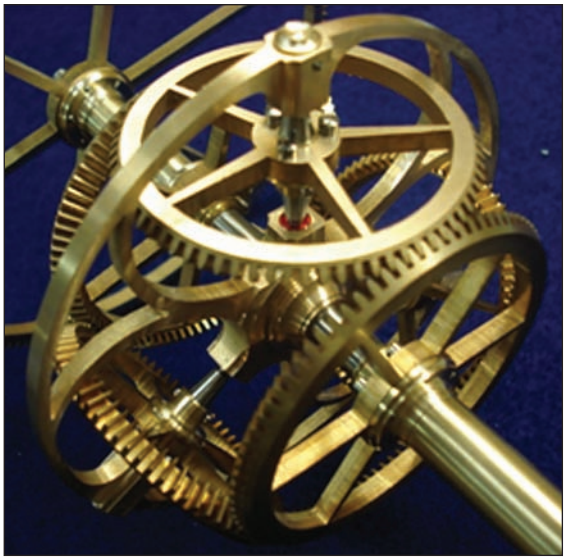

Figure 29. Differential drive for dual time train remontoire.

Figure 30. Organic "ivy /trees" comprising the middle frames.

complications and all of the behind-the-dial-work. You can see several video clips of the clock functioning both when it was between the temporary plastic frames last December as well as after the transference to the metal frames at: http://www.youtube.com/user/fgtyc.

I hope this article conveys a bit of the effort, excitement, and commitment that my partnership with Buchanan has in the creation of this clock, to you, the reader. I believe that we are making something very special and will stand the test of time as a horological artifact of significance. You can see the advancement of this project month by month at: http://www.my-time-machines.net/astro_index.htm. You may also email me at: mfrank1@rcn.com or through the website, and comments, criticism or just plain conversation are always welcome.

Notes

1. Buchanan can be reached at: clocks@buchananesq.com
2. The website paper is at: http://www.my-time-machines.net/my_current_project3.htm
3. For further reading, Jens Olsen's Clock by Otto Mortensen.
4. http://www.tuerler.ch/5en.html
5. The 16 astronomical functions are as follows:
   1. Equation of time
   2. Sidereal time

   The 400-year perpetual calendar indicating:
   3. Day
   4. Date
   5. Month
   6. Year
   7. Leap year indication
   8. Sunrise/sunset horizon shutters
   9. Sunrise/sunset time indication
   10. Moonrise/moonset shutters
   11. Moonrise/moonset time indication
   12. Moon phase globe
   13. Planisphere
   14. With roving Sun showing travel through the Zodiac
   15. Tellurium featuring the Earth, Moon, and Sun system
   16. Grand orrery, Mercury through Saturn, with Jupiter and Saturn each having five orbiting moons as known in the late 1700s.

About the Author

Mark Frank has been collecting clocks for the past 15 years, but only those where he can view the movement. A clock that is in a conventional wood case hides most of the fun! Hence the collection of skeleton clocks. Eleven years ago he found an old French tower clock in an architectural artifacts store—WOW, a giant skeleton clock! Now he has over 30 tower clocks and a similar number of skeleton clocks. Both collections have an emphasis on interesting mechanical contrivances. Many have remontoire, some with a tourbillion or unusual escapements like grasshopper, detent, coup-perdu, and various gravity types. A few years back he discovered what he thinks is an undiscovered niche in horology: bank vault timers. Again one can see the movements within the beautifully machined and damascened time lock cases. Most of the movements are from known makers like E. Howard, Illinois Watch Co., Waltham, and Seth Thomas.

Mark is very interested in communicating his interest with others. His website (www.my-time-machines.net) is not a simple show and tell; it is designed to inform. A section deals with the step-by-step process of restoring an old tower clock movement. There are stop-action films and audio/video to explain the rationale, design, and function of remontoire. He has written a brief overview on the evolution of design and mechanics of tower clocks, also downloadable from the site.

All article photography by Buchanan.