

Circumlnar Transmissions

Issue One

slum joneworlds fturrows solderpunk durtal
wholesomedonut

May 2021

SHELL-TO-SHELL

Circumlunar Transmissions

Issue One

May 2021

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most things were back of the prime examples of comers to even stand on and explore once (or if ever) they choose to get involved in FOSS gaming newcomers. It's hard to use at first, hard to look at always, and sometimes hard to find other people to play it with. Those three things will nail the coffin of any fledgling game shut. That concept were still common. That's a given. And it is where dial-up connections were still common. Java (yes verily, begone derstandably opaque to foul JVM!), which for all its' foibles makes a very easy cross-platform dis-tributable program. It's solidly a relic of an earlier time of online gaming, where dial-up connec-tions were still common. game shut. That concept are also interested in free and open source software to consider the prospect of inviting others into this world of free-as-in-freedom/beer/whatever ple that A) aren't tech-nically inclined, B) don't have a heart that beats for free-as-in-freedom, and C) want something all walks of life, signif-icant adoption of FOSS fine myself to a much smaller content base with an even smaller player-base to share it with. Call me the gaming uptick in talent, contribu-tion and playerbase that I don't see the point in but I don't see the point in a highly detailed com-puterization of a niche franchise that has a fan-base spanning genera-tions. However, it also stands out to me as one platform for those new-

At the End of the Day

I encourage people who play video games which art style, or UI/UX. So, I leave it to you to are also interested in free and open source software to consider the prospect of inviting others into this world of free-as-in-freedom/beer/whatever ple that A) aren't tech-nically inclined, B) don't have a heart that beats for free-as-in-freedom, board new people from and C) want something all walks of life, signif-icant adoption of FOSS fine myself to a much smaller content base with an even smaller player-base to share it with. Call me the gaming uptick in talent, contribu-tion and playerbase that I don't see the point in but I don't see the point in a highly detailed com-puterization of a niche franchise that has a fan-base spanning genera-tions. However, it also stands out to me as one platform for those new-

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Preface

BACK IN FEBRUARY, around the time of the ogre incident, Jones wondered out loud on the produced is largely still up in or capsule. That is, any-one can clone the git repo on their own gopherhole and Gemini by whoever zine over time, but cur-rently what the zine is would like to host a copy on their own gopherhole or capsule. That is, any-one can clone the git repo on their own gopherhole and serve its contents from their own episodic. The strategy of this first run has been to just get it out there. Rather than as we proceeded to howl prematurely exhausting where and how to bi-host our energy on determining what it should be, or pidgeonholing ourselves into a niche or format without actually having inaugural issue, at least. Anyone who has had ing the many phlog and the pleasure of persuading what we get. So for this first issue, we have what has been en-dearingly termed a "topic lunarspace will be aware of the impressive diver-salad." And I believe it has been a pleasure to contribute something to this wonderful com-munity of thoughtful and creative individuals whom I respect and admire sincerely. During my relatively brief inhabita-

tion of the Zaibatsu, I've found gratitude and pride for this habitat and its inhabitants, and the smolnet ecosystem at large, that I present to you this first issue of our smolzine, *Circumlunar Transmissions*.

mieum
APRIL 25, 2021
INCHEON, KOREA

dium takes away from the moment-by-moment gameplay, forcing everybody to get ox-in-the-mired over details that don't matter overall instead of letting their big stompy robots blow each other up.

Megamek works wonders in that regard. A game of Classic Battletech that could easily take 5 or 6 hours in person without any sort of calculator apps or an otherwise breakneck pace of gameplay and rules-lawyering will only take an hour or two maximum with Megamek. It's a godsend for a hobby that would otherwise be relegated to local play over predetermined days, not a "Hey want to play a match? Sure!" kind of casual pickup on a boring afternoon.

But It Isn't All Sunshine and Rainbows.

Nope! Megamek is, in my humble and donut-shaped opinion, a terrible example of UI and UX. I played a round recently, and another aficionado of

the series played against me. Quoth my opponent: "This program looks like something out of Windows 95." Neither of us had played the most recent version of the game. I hadn't touched it in a year at least.

Some changes were welcome, and the development progresses smoothly. But it's still just as much a spaghetti plate in terms of user experience: configuration options laid out in long lists of check boxes organized by multiple top-window tabs; a decidedly 15-years-old design language that clashes with modern perceptions of UI and UX (which is bad considering that taking in new blood is crucial for both userbase and developer contribution reasons); and the final nail in the coffin is the fact that the much easier and more recent Alpha Strike ruleset isn't included at all by default, to my knowledge.

You might be able to configure something like that using plugins, but we're already putting the cart before the horse at that point.

To Be Fair

The project started in 2000. It's 21 years old in some places, if only in logic and not literal syntax. It's written in Java. And it's been a community effort by dozens of talented people over the decades. The fact that it's alive at all is impressive, but so's the fact that the franchise whose boardgame it emulates even has a fanbase still. BT fans aren't quitters, certainly. And this is all considering the fact that trying to automate, obfuscate and de-FUBAR the mountain of minutiae that Battletech's rulesets and technical data (on a per unit and per variant basis no less) is a monumental task. I can hardly think of a video-game adaptation of a more complex board game that does a better job, in proportion to the complexity of the physical source material and gameplay flow.

So considering it was made in the waning days of Win98 (because Windows ME doesn't exist and you can't convince me otherwise) it's expected that it's ugly as

secure) instead of just one who isn't tech savvy adding it on Steam or Epic or Microsoft Store or down the right version of a FOSS game from a PS/Xbox or some-other thing, there is a solid code repo (or heaven for-taking and giving damage to individual components, weapons and armor locations in a some- is like asking ME to diagnose a car's problems what realistic and highly detailed simulation of light and a screwdriver. I 31st-century warfare. To alleviate the issue of significant calculation department. Without the single-action-attack-or-walks of life; the UI and UX of FOSS gaming needs to be on-par with modern commercial offerings; this means all the way from landing on a page, to funneling through a sales conversion or free download, to playing the game with their friends needs to be understandable, un-obtrusive and transparent. A good example of a FOSS game that has plenty of vehicle whose armor is already exposed on its' left flank. There are plenty of gognards out there who know these rules well and can do half the game in since the 1980s and is going, number-crunching, generally. They're very skilled in a multitude of particular subset of people even enjoy. All in the name of combined-arms puters. But asking some-

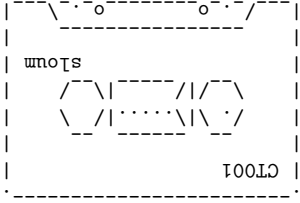
one who isn't tech savvy adding it on Steam or Epic or Microsoft Store or down the right version of a FOSS game from a PS/Xbox or some-other thing, there is a solid code repo (or heaven for-taking and giving damage to individual components, weapons and armor locations in a some- is like asking ME to diagnose a car's problems what realistic and highly detailed simulation of light and a screwdriver. I 31st-century warfare. To alleviate the issue of significant calculation department. Without the single-action-attack-or-walks of life; the UI and UX of FOSS gaming needs to be on-par with modern commercial offerings; this means all the way from landing on a page, to funneling through a sales conversion or free download, to playing the game with their friends needs to be understandable, un-obtrusive and transparent. A good example of a FOSS game that has plenty of vehicle whose armor is already exposed on its' left flank. There are plenty of gognards out there who know these rules well and can do half the game in since the 1980s and is going, number-crunching, generally. They're very skilled in a multitude of particular subset of people even enjoy. All in the name of combined-arms puters. But asking some-

Give People the Benefit of the Doubt

Enter the Mech Man

People are intelligent, generally. They're very skilled in a multitude of particular subset of people even enjoy. All in the name of combined-arms puters. But asking some-

The Circumlunar Mixtape



sloum's covid-year playlist

THE Circumlunar Mixtape is an ongoing series for Circumlunar Transmissions where one user per issue shares 10 tracks they have been listening to. Some are old some are new. It has been a weird year and this is a kind of weird mix. I provided Bandcamp weblinks for each track except the Charlie Parr, which is a Youtube link because I like this song live and this is my favorite performance recording of it and the recording doesn't appear on any of his albums. Enjoy!

Forward Beckons Rebound

by Adrienne Lenker
from Songs

<https://adriannelenker.bandcamp.com/track/forwards-beckon-rebound>

1 The Circumlunar Mixtape

- 1 **Catamaran**
by talons'
from *Songs for Boats*
<https://talons.bandcamp.com/track/catamaran>
- 2 **Possessed by the Devil**
by Charlie Parr
(Live)
<https://www.youtube.com/watch?v=P46hGYUycoE>
- 3 **Some Voices**
by Pinback
from *Some Voices*
<https://pinback.bandcamp.com/track/some-voices>
- 4 **Get to Know You**
by Tomo Nakayama
from *Meloday*
<https://tomomusic.bandcamp.com/track/get-to-know-you>
- 5 **Just a Cloud**
by Lusine
from *Sensorimotor*
<https://lusine.bandcamp.com/track/just-a-cloud-feat-vilja-larjosto>
- 6 **Good Morning Captain**
by Slint
from *Spiderland (Remastered)*
<https://slint.bandcamp.com/track/good-morning-captain-remastered>
- 7 **Step Into You**
by Hum
from *Inlet*
<https://humband.bandcamp.com/track/step-into-you>
- 8 **Kingfisher**
by Windhand
from *Grief's Infernal Flower*
<https://windhand.bandcamp.com/track/kingfisher>

Why I Still Game Proprietary

by wholesomedonut

Proprietary Gaming Isn't All Bad

SINCE getting into the FOSS community, I see a lot of pushback towards the gaming industry as a whole. I can see why: DRM runs rampant, terrible business practices regularly conflagrate internet forums, anti-cheat programs are basically consensual (and mandatory for official online play in some cases) trojans, and to make it all worse it costs a mint to get into the hobby nowadays due to scalpers and crypto miners running rampant in the market.

I agree with all of those observations. They tire me. They concern me. They frustrate me daily.

However! There are still reasons -not- to go the route of some I see in the FOSS world and eschew gaming altogether on anything but a FOSS platform, with FOSS games, because...FOSS. That argument is just as dumb in practice, because it's an artificial limitation that stands on somewhat subjective, opinionated reasoning. "But wholesomedonut, thou angereth me!" I hear in the imaginary comments section because this is Gemini and you can't do that. I am certain you will find peace through measured contemplation and a cup of whatever warm or cold liquid you enjoy.

Why Do I Use Steam?

Well...everyone else that isn't a computer nerd usually does too. And the overhead for getting people of minimum technical understanding (that like playing video games) into FOSS gaming generally is much more costly in terms of mental and social capacity than the clout I usually have with my friends or family on such matters.

King's English: If I have to instruct them to download the latest version of the game directly from Github in the Releases tab, or from some random website they've never heard of (even if it looks nice and is HTTPS

hearth fire as it converges and drink your morn- bers no longer live near to one another at the sunset and share a joke or two of a loved one's life. Now with your fellows. One of them ruefully remembers a fire on a cold winter's morning. Other's gather that it is his day to do the wash their bodies late in close to you, hoping to dishes; they are piling up as the others finish and go. This time, like its later double, is a short space of wait too. You each rub and blow warm breaths intimacy before separa- onto your hands and com- ment on the cold, and you like the birth of a child for whom the family cares. Such brief familial inti- as the flames devour the larger pieces of wood. The hope builds and blossoms day when hearth fires and the world offers in this home are all but forgot- ten. We now only focus fire roars madly as you But, not so for the elderly, wooden pyramid to col- lapse. When there are your breakfast over them coals left mostly, you cook far from one another that, too often, family mem-

Did old Thomas Hobbes have a point?

9

Nue
by Nils Frahm
from *Wintermusik*
<https://nilsfrahm.bandcamp.com/track/nue>

The Hearth of the Matter

by durtal

IT SEEMS that Kepler first used the Latin word ‘focus’ in 1604 to refer to ‘the point of convergence’ in the mathematical sphere. It is possible that this is an analogical use of the term and may reference the point of light created with a lens. You probably know what I mean. I remember another child showing me a trick with a magnifying glass outside one sunny day. He quickly adjusted the glass’s height over my forearm to effect a sharp pain as the converging rays burned a hole in my skin.

Hobbes brought ‘focus’ into broader English parlance nearly fifty years later. I don’t know if he did this with a magni-

fying glass or not. But, Hobbes is certainly not my favourite philosopher. With its particular take on human nature, he published *Leviathan* about the same time he popularised a word whose use is ubiquitous but whose original meaning is too often unknown. Sometimes the abstractions of science and a specific sort of philosophy separate us from the mundane realities of life in unfortunate ways.

Ironically, the political philosopher who espoused that humans are “all take and little give” used a word that belied his contentions in the original. Focus is the Latin equivalent of the Old English word ‘hearth’.

People still used the latter term in my youth, especially in rural regions. Phrases like “hearth and home” and “keep the home fires burning” catch something of its ethos. The hearth was where household members gathered to cook or to work by the hearthstone’s firelight. In its warmth, children sat to hear the stories of the family and community after dusk. Kith and kin entertained themselves with music and drinking and dance nearby. In some cultures, families kept ancestral bones beneath the hearthstone. Here was a point of convergence in the human habitat.

The rising or setting sun reminds me of a

Ask Jone

W. asks:

I have a strained relationship with my sister. What are some things I can do to help repair it?

I REMEMBER my dad dad's thinking along the same lines as me, because other box of cans, and he starts screaming and yelling about how he hates turkey-a-la-king. And he gets so mad he accidentally knocks over the stack of cans. And some want them. And he knows that, but he keeps on getting tires anyhow.

And so we go on like this for weeks: I come by and put like 5 more cans of turkey-a-la-king on his kitchen counter, and he stacks a few more snow tires outside his door for me. And all this stuff is after can of turkey-a-la-king. You ever try that one from Chunk'n'Dunk? Gradually getting madder and madder at each other. Until one day I go over there with an- dad's thinking along the same lines as me, because other box of cans, and he starts screaming and yelling about how he hates turkey-a-la-king. And he gets so mad he accidentally knocks over the stack of cans. And some want them. And he knows that, but he keeps on getting tires anyhow.

And so we go on like this for weeks: I come by and put like 5 more cans of turkey-a-la-king on his kitchen counter, and he stacks a few more snow tires outside his door for me. And all this stuff is after can of turkey-a-la-king. You ever try that one from Chunk'n'Dunk? Gradually getting madder and madder at each other. Until one day I go over there with an-

then there's this weird sound by the front door. When I get out there to check it I find that coincidentally the big pile of snow tires out there has also fallen over, and it's crushed some unlucky little gnome who must have been milling around by

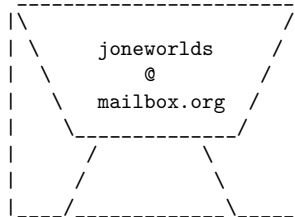
there. Those things are so bad at staying alive, I just can't believe it sometimes.

Anyways, if you're looking to patch things up with your sister, I would say maybe don't do it with canned soup, or snow tires. It sure didn't help

us any. It just wasn't a good result for anyone, especially for that gnome. Or if you have to go with soup, at least stick with the meatball-carrot one. It's actually not bad.

Thanks for writing in. I hope that helps.

*Do you have a problem?
Send your questions to:*



discover that the SI system of units defined the second based on some-

thing other than Earth's rotation when it was established in 1960, seven

years before the caesium definition was adopted.

References

Nelson, R., McCarthy, D., Malys, S., Levine, J.M., Guinot, B., Fliegel, H., Beard, R., & Bartholomew, T. (2001). The Leap Second - Its History and Possible Future. *Metrologia*, 38, 509-529.

Ronningen, Ole Petter. "Time-nuttery 101". <https://efos3.com/TimeNut.html>

Allen, Steve. "UTC might be redefined without Leap Seconds".

<https://ucolick.org/sla/leapsecs/timescales.html>

instead repeat the time-
ing to trade during the
leap second. Given that
some software will fail to
tam 23:59:59 twice (since
ing in :60). Other systems
“smear” the leap second
out over longer time peri-
ods, like 24 hours, to avoid
problems associated with
bad idea. Of course, sim-
up with a new ugly hack
two alternatives: coming
outages around this time,
ing errors compared to
non-smearing systems.
Some systems, of course,
forget to do anything at
hour, but Air Traffic Con-
trol has to stay up 24/7.
seconds to date have been
It's no surprise that in-
has been needlessly fid-
in the tech industry are
calling for leap seconds
ware out there which has
worked correctly so far
people are very unhappy
but will fail the first time
a second is removed. And
consensus on what to do
the Earth's rotation is go-
ing through a bit of a fast
phase right now, so the
first negative leap second
might be looming on the
horizon.

The software interop-
erability situation at the
time of a leap second is
likely to get worse. The
seconds cause are only
world, the headaches leap
ware continues to eat the
leap second. As soft-
the future holds for the
ly find on the web (full
citation below), along
with, as always, follow-
ing Wikipedia links wher-
ever they take you. Along
the way you can learn
atomic definition of sec-
and that means that get-
ing the millennium old no-
GPS Time (GPST) and Ter-
restrial Time (TT), and

More!

But Wait, There's

by fffurrows

**Passing Thoughts of an
Impractical Idealist**

of manifestos that stop the flow of cre-
ativity, passion, and progress. At the risk
of making the problem worse, I proffer:

Our ancestors stood on the banks
of the Euphrates and cast their
ideas into the inexhaustible current.

First they cast in words, ephemeral.
Then they learned permanence; epochs
brought clay tablets and papyrus, script
and type, bits and clouds.

Let your mind move freely, become a
seeker

Accept that knowledge is scattered
broadly

Find kernels of truth and germinate
thoughts

Permanence dammed the river, a log-
jam of ideas tossed in as if each was
a consummate standard. Life-giving
waters slowed, intelligence waned, the
elastic mind seized and crumbled. The
word manifesto dates to the fourteenth
century, but the notion dates to our ear-
liest written conclusions.

This is not the manifesto to end all
manifestos. It is a message in a bottle
that few will find. It is a loose model
for dealing with the mountainous dam
in

Take something from every ideology,
fear nothing
Subscribe to that which you find value

Manifesto of a Granular Ideologue

From a Message in a Bottle, Sitting Atop the Dam of Manifestos

Mistrust labels, they carry unimaginable baggage

Acknowledge all that came before, but accept the utility of your journey

Never believe that you have the best vision for the world

Don't try to fashion the world to your ideals; your ideals are cursory

Be a maximal minimalist, distill purity from immensity

Find, purify, share, repeat

To conclude means to cease to grow

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allowed when necessary to keep the time scale locked to the movement of the sun across the sky.

So far, there have been 27 leap seconds defined, although UTC and ATI are today exactly 37 seconds apart - the other 10 seconds come from hacks applied before leap seconds were established in 1972. All of them to date have been insertions rather than removals. They don't happen on a regular, predictable basis, like leap years (which are an adjustment for the fact that the time it takes the Earth to orbit the sun once, defining a year, is not perfectly divisible by the time it takes the Earth to rotate once, defining a day). Because the Earth's rate of rotation fluctuates randomly, sometimes slowing down and sometimes speeding up, astronomers need to be actively on the lookout for excessive values of DUT. When it's decided a leap second is needed - it's the IERS who makes that call - they are announced at least six months in advance. They're allowed to occur on either June 30th or December 31st, and

are inserted or deleted at midnight UTC (which is the middle of the day in some time zones, of course) on those days. At the time of writing, the last leap second happened on December 31st, 2016. In principle, six months is enough advance warning that nobody doing anything which depends on precise time synchronisation should be caught by surprise when a leap second rolls around. In practice, it's not always so simple.

Increasing Implementation Burden and an Uncertain Future

Leap seconds have always had their critics, but at the time they were adopted, their benefits arguably balanced their associated hassle. 50 years later, this hack is starting to show its age. The advent of cheap and reliable GPS technology means that celestial navigation at sea is now rarely a matter of life or death (although some sailors still appreciate the relative simplicity of the technol-

ogy it relies on), removing some of the argument for making sure UTC stays in lock step with the Earth's rotation. At the same time, the internet has come along: a massive network of computers talking to each other, with the frequent need for activity on one to be synchronised with activity on another (hence tools like the Network Time Protocol, NTP). Computer programmers *hate* leap seconds, for the same reason they hate Daylight Saving Time: they complicate time calculations (you can't accurately calculate the number of seconds between two UTC timestamps without consulting a table of when previous leap seconds were inserted) and are a frequent cause of confusion and errors, when one system implements them differently from another its trying to interoperate with.

Affordances for leap seconds are often added to software as an afterthought - if they are added at all. Some systems represent the extra second using the timestamp 23:59:60, but others

casting TAI instead of UT, make everybody happy. ugly hacks. It cannot be Enter Coordinated Universal Time, or UTC - at any other way, as UTC accurate as TAI drifted last, something normal further out of synch with people have heard of! The abbreviation UTC incompatible properties of a timescale: perfectly and improved" TAI time between the English abbreviation CUT and the French abbreviation TUC (for "Temps Universel Coordonné"). This is somewhat fitting, because UTC itself is a strange compromise time scale between UT and TAI. Like TAI, UTC is an atomic time scale, defined, but for almost poses, which could easily lead to confusion, on January 1st in 1960 the choice was based on caesium atoms, allowing scientists and engineers around the world to calibrate their instruments and reliably measure time intervals but today the torch has been passed to a combination of the International Bureau of Weights and Measures, or BIPM, further away from UT, back into alignment by either direction, UTC is kicked into a single second on the French "Bureau International des Poids et Mesures" and the International Earth Rotation Service, who have the gall to abbreviate the *English* form celestial navigation of their name and go by IERS) defined yet another time scale, in an attempt to achieve the best of both worlds and

Coordinating Chaos

Instead of broadcasting two different time signals for different purposes, which could easily lead to confusion, on January 1st in 1960 the choice was based on caesium atoms, allowing scientists and engineers around the world to calibrate their instruments and reliably measure time intervals but today the torch has been passed to a combination of the International Bureau of Weights and Measures, or BIPM, further away from UT, back into alignment by either direction, UTC is kicked into a single second on the French "Bureau International des Poids et Mesures" and the International Earth Rotation Service, who have the gall to abbreviate the *English* form celestial navigation of seconds in a day is not absolutely fixed at 86,400 by definition. There are 86,401 and 86,399 are also cal compromises, using achieved, like all technical synchronization is most always a UTC day, but

What's the Deal with Leap Seconds? A Brief Overview of Timescales

by solderpunk

Astronomical Seconds

MHY is a second as long as it is, and not a little shorter or a little longer? This is a seemingly simple question which leads down a deep and delightfully twisted rabbit hole. It's something that I wish Neal Stephenson had written an epic long, inexpli- cably compelling 1990s Wired article about, in the spirit of his "Mother Earth, Mother Board" or "In the Kingdom of Mao Bell". But he didn't, so you're stuck reading this,

instead: a brief, incomplete, possibly slightly inaccurate overview based on my own characteristicly obsessive reading like, a second is the time it takes the Earth to rotate once. Or, if you take one 240th of a degree, out of the full 360. End of story, right? Well, no. This is a perfectly sensible way to define time - for some applications, it's the best way to do it. This astro-nomically defined time scale is still in use today in certain contexts. The official name of its modern incarnation is Universal Time, or UT (technically, there are a minutes in an hour and 24 60 seconds in a minute, 60 single revolution about its axis. And since there are 60 seconds in a minute, 60 minutes in an hour and 24

few subtly different variants, denoted UT0, UT1 and UT2, but we'll gloss over that here). The official determination of UT nowadays is based mostly on measurements made at observatories tracking the movement of distant radio sources across the sky as the Earth rotates. This is easier than making precision measurements of the sun, but is still measuring the exact same thing.

Earth is a Nice Place to Live, but it's not the Best Clock

The problem with an astronomical definition of the second is this: the Earth doesn't actually rotate at a perfectly constant rate (it wasn't until the 19th century that we could build clocks accurate enough to notice this). In fact, the Earth's rotation is slowing down. Very slowly, of course. Every century, a complete rotation takes about 2 milliseconds longer than it used to. The rate of slowing down is not steady. Some years the change is more and other years it's

less. In fact, even though the overall trend is one of slowing down, some years the rotation actually speeds up. The dynamics of the process are complicated, and we can't make accurate long term forecasts. Gravitational interaction between the Earth and the moon is the primary driver, but the movement of tectonic plates and friction between Earth's surface and its atmosphere and oceans have their say, too. The Indian Ocean Earthquake in 2004 was powerful enough to shorten the length of a day by 2.68 microseconds. There are even periodic variations in the rate of rotation that we just don't understand the cause of yet. But the take home message is that, whatever the causes, astronomical seconds actually have small, random fluctuations in their duration over long time spans. If you define the second by looking into the skies, no two seconds are exactly the same.

That's a pretty inconvenient property for the official definition of a fundamentally important unit like the second to

have. For most of the time this definition was used, the fluctuations were smaller than we could reliably measure. Certainly, they weren't enough to have an impact on everyday life. Nobody was going to be late to lunch because of the Earth's unsteady rotation. But by the 20th century, scientific and technological progress meant these tiny fluctuations started to matter, as we began measuring natural phenomena and building machines which operated on very small time scales. A 10 megahertz radio oscillator, for example, has a period of 0.0000001 seconds - only 100 nanoseconds! Gigahertz radiation, which is important in radio astronomy and was used for communications and radar during WWII decades before it came to underpin modern technology like GPS, WiFi, and mobile data networks, has periods measured in *picoseconds*. Even very, very small variations in the length of a second are enough to make the measured frequency of radio waves change, even if the *actual* frequency

is fixed. Modern technological society simply couldn't be built using a wobbly clock like the Earth.

Atomic Seconds

Fortunately, in the 1950s, atomic clocks were invented which kept time better than any previous mechanism. I'll gloss right over the details, but suffice it to say, we came up with a new way to define the second which involved measuring the properties of caesium atoms instead of looking at things moving through the sky. In 1967, the relatively young International System (or SI, for the French "Système International") of units redefined the second on this basis. The new atomic second was defined such that it had the same length as the astronomical second in use before it, as far as measurements at the time could tell, but it had the added bonus that the length of the second was then fixed and unchanging. Caesium atoms at a given temperature "vibrate" (very loosely speaking) at a fre-

quency which, as far as we can tell, is completely and perfectly stable, and which can be measured very accurately in a sufficiently advanced laboratory.

With the arrival of atomic seconds, a new time scale was also defined: International Atomic Time (or TAI, for the French "Temps Atomique International"). At midnight on January 1st in 1958, TAI and UT were perfectly synchronised. Ever since then, they have slowly but surely drifted apart. The seconds of TAI are of perfectly unchanging length (as measured by averaging hundreds of atomic clocks all over the world), but the seconds of UT fluctuate with the Earth's rotation. The accumulated drift up until now is a little less than 40 seconds, but it will continue to grow, without limit. And while the perfectly uniform seconds of TAI make it the perfect tool for some tasks, this drift apart from UT makes it problematic for others. If you go outside at noon UT in Greenwich, England (or anywhere else at 0 degrees longitude), the sun

will *always* be high in the sky. This is true today and it will be true in a thousand years. Because UT is fundamentally linked to the Earth's rotation, TAI, on the other hand, is fundamentally divorced from it. Thousands of years in the future, there will come a day when, according to TAI, the sun rises in Greenwich at midnight.

This isn't just an abstract concern for the distant future. In the late '50s when TAI was defined, it was still common for ships at sea to figure out where they were by using a sextant to record the position of the sun above the horizon at a certain time and consulting a printed table of conversions. For this purpose, ships carried the most accurate clocks they could afford, and compared them regularly against true UT time using time signals broadcast by radio stations all over the world. Celestial navigation works very well when using a timescale which is tightly linked to Earth's rotation, and hence the position of things in the sky. But if the radio time signals switched to broad-