Introduction

In this paper, we discuss Karlheinz Stockhausen's article "*...how time passes...*" [Stockhausen1957], in which he proposes a "new morphology of musical time". This new morphology was made necessary by the failure of his serial system to strictly control all the parameters of interesting musical sound, and grew out of his pioneering studio work in pure electronic music. It marked Stockhausen's embarking on a new direction of investigation and composition, in which he adapted his serial system to control statistical and qualitative musical parameters, rather than deterministic and quantitative parameters which had proved self-defeating. It also opened up the world of the micro-structure of sound, in which he began to think about the smallest atoms of acoustical phenomena.

His new morphology of musical time is reflected, in the article, in excerpts from his *Zietmasse* (Time-measures for Winds), *Gruppen* (Groups for three orchestras), and *Klavierstuck XI* (Piano piece #11), and, soon after the article, in works including *Zyklus* (Cycles for Percussionist) and *Carre* (Square for Four Orchestras). His effort to open up the micro-structure of sound is reflected in *Gesang der Junglinge* (Song of the Youths), and finally, in the monumental *Kontakte* (Contacts for Piano, Percussion, and Electronic Tape), after which he abandoned the composition of pure electronic music ([Heikenheimo 1972]).

As a turning point in the history of 20th-century compositional theory, his article is an important historical reference. It was also controversial, and we will discuss some of the criticism it engendered in the literature. Although much of Stockhausen's technical details are subject to criticism, we will mention some of the modern acoustical and signal processing theories which could form the basis for a new investigation into this material.

In our first section we explain the concept of serial composition, especially the German and French experiments in total, or integral, serialism leading up to the article. We mention serialism's development from concepts in the music of Arnold Schoenberg, Anton von Webern, and Oliver Messiaen. We present some early criticisms of total serialism, by Iannis Xenakis, Roger Sessions, and others.

In our second section, we present our exegesis of Stockhausen's article. In the third section, we discuss the criticism published in response to the article, and briefly mention psychoacoustical "stream" formation, signal processing in the time and frequency domains, the power of mixed time-frequency representations, the recently developed wavelet transform, and the theory of granular synthesis. These are technical tools, unknown to Stockhausen, which show promise today as tools for further exploration of the morphology of musical time.

In the fourth section, we delve into detailed examples, deriving a durational and metronomical time series from a chromatic pitch series. We also discuss the breakdown of Stockhausen's total serial control, in the success of his attempt to connect the macrotime and microtime domains structurally.

Finally in the last section we compare Stockhausen's "new morphology of musical time" with the book written in 1919 by Henry Cowell. Cowell's insight, in his application of the harmonic overtone series to musical rhythm, predated Stockhausen's by 35 years. But Stockhausen was more interested in the applicability of this "serial" composition method to duration. We compare and contrast proposals made by Cowell and Stockhausen for the construction of new musical instruments capable of performing according to their rhythmical ideas.

Scientific Commentary

In this section, we discuss some commentary and criticism, by physicists and others, about Stockhausen's article "*...how time passes...*". His unconventional, perhaps objectionably incorrect use of terminology like "phase", "quantum", and "formant" was unacceptable to the physicists, and some of his unclear or faulty assumptions need repairing before his conclusions can be accepted. But aside from the technical problems, does Stockhausen's article have any remaining scientific value? Is there, perhaps, musical value, apart from scientific value, even if it lacks the latter?

To answer this question, we present commentary from the British magazine *Composer*, a scientific critique from the premiere issue of the American journal *Perspectives of New Music*, by physicist John Backus, and articles from Stockhausen's journal *Die Reihe*, by physicist Adriaan Fokker and composer Gottfried Michael Koenig.

In the British music journal "Composer", Alan Walker wrote

"The technical jargon in Die Reihe is notoriously difficult. Purporting to explain the latest developments in the theory and practice of new music, from serialism to electronic music and beyond, the pages of Die Reihe comprise a rich, terminological jungle through which I, for one, have rarely been able to hack my way. There are, of course, two rational explanations for my failure. Either I miss the point, or there is no point to miss...." ([Walker 64a], p.24)

Physics professor John Backus, in his scathing criticism, wrote

"Repeated reading and persistent study of many passages [in the various issues of Die Reihe, including the one with "...how time passes..."] leave us still ignorant of their intended meanings. We are continually baffled by a technical language with which we are unfamiliar. In our frustration we may begin to wonder if perhaps the authors are as confused as their language appears to be, and if the unintelligibility is our fault or theirs....

"... We wish to see if the scientific terminology is properly used, to see if the charts, graphs and tables have any real significance, and to determine the technical competence of the material from the scientific standpoint. If it measures up creditably to these criteria, all well and good; if it does not, we will quite justified in dismissing as worthless all of it that does not make sense by ordinary standards." ([Backus1962], p. 16)

At the very beginning of the article in question, Stockhausen states that "Time-intervals between alterations in an acoustic field are denoted as 'phases'" [p. 10]. Thus begins the first disagreement for Backus. Stockhausen is referring to the fluctuations in air pressure that we perceive, when they reach our eardrums, as sound waves, and to the time intervals between maxima or minima of this pressure.

According to Backus, in a system undergoing some sort of periodic vibration or oscillation, "the phase of the periodic quantity, for a particular value of the independent variable, is the fractional part of a period through which the independent variable has advanced, measured from an arbitrary reference" ([Backus1962] p. 18). This is attributed by Backus to the reference book American Standard Acoustical Terminology, definition 1.18.

In other words, the term "phase" is conventionally used to denote a fractional part of one vibrational period in a simple harmonic, or "periodic", motion. Around a circle, for example, where the total length of one circular revolution, or period of rotation, is subdivided and measured usually by 2pi "radians" or 360 "degrees", a position 1/4 of the way around from a chosen point or origin (conventionally the rightmost point on the circle, where it intersects the "x-axis" if the zero is at the circle's center) would be said to have a phase of pi/2 radians, or 90 degrees (a "right angle"). No matter whether the position was reached through 1/4 of a revolution, or 1 1/4 revolutions, or 29 1/4 revolutions, the phase would still be the same, 1/4 of a period, pi/2 radians.

Stockhausen is apparently using "phase" to denote the whole period, rather than the fractional part that the term usually refers to (and he is also trying to generalize it to denote non-periodic motions too, which further complicates matters), so in his terminology, one might refer to the "phase duration" of 2pi radians for what the rest of the world denotes as one period. Backus questions why Stockhausen is deliberately misusing standard acoustical terminology in this fashion. ([Backus1962], p. 18)

Adriaan Fokker, another physicist, writes

"The interval of time between two repetitions of the same phase is called, simply, a period. There is no need whatever for a new word. After all, as has already been said, phase is not a new word at all. It has a well defined and generally accepted meaning. Something like sepha -- with the syllables reverted -- would have been a new word.

"It seems that the author has some motives in avoiding the word 'period'. Has it the stigma of being handed down by tradition? Let us look, then, for another term. I find in my dictionary the English word 'while' for the Dutch word 'poos'. I venture this proposition: let time-intervals be called 'whiles'...." ([Fokker], p. 68)

Fokker later rephrases one of Stockhausen's complicated serial examples, using his "while" in place of Stockhausen's mis-appropriated "phase", and we discuss this in the next section.

Backus next objects to Stockhausen's statement "Proportions serve for more exact definition -- one phase is twice, thrice as long as another. In order to fix proportions, one chooses a unit-quantum, and this is usually based on time as measured by the clock; we say one phase-duration lasts one second, two seconds, a tenth of a second...." ([Stockhausen 1957], p. 20) because, in Backus' words, "in physics, a quantum is an undivisible unit; there are no quanta in acoustical phenomena, and besides, Stockhausen discusses `subdividing' a quantum, which is meaningless...." ([Backus 1962], p. 18)

In subatomic physics, the unit of energy representing the smallest possible jump from one level to the next higher or lower one is denoted as a "quantum", and it is a fundamental, indivisible unit. Clearly Stockhausen is taking liberties when he refers to a measurement of one second of time as a "unit quantum". (But we note the "acoustical quantum" [Gabor 1946, 1947], which is in fact an indivisible unit of information)

Backus [p.18] also points out the defects in Stockhausen's first example, in which a pair of impulses, apparently (the assumptions are not very precise about exactly how many impulses there are, nor about the acoustical properties of the impulses themselves), is to be heard, with the distance between successive impulses gradually shortening from 1 second, to 1/2 second, to 1/4, 1/8, 1/16, 1/32 second, etc. At first they will be heard separately, but after the distance between them grows short enough, they will merge into a sensation of a continuous tone at a particular pitch. Stockhausen is concerned with the threshold at which the perception of duration merges into the perception of continuous pitch, which is approximately at 1/16 second between impulses.

In acoustical theory, an "impulse" is an infinitesimally short transient sound-object, basically the short est possible "click". Clearly this is not what Stockhausen was referring to in his article; he was trying to describe the output of a modified pulse wave oscillator, an electrical impulse generator, that was available for his use in the Cologne Radio electronic music studio ([Manning1985], p. 73), which put out short but measurable bursts of sound at definite pitches (i.e. when their duration was long enough to cause a definite pitch sensation), with control over the duration between successive impulses.

Backus shows that if two impulses are heard with a time-interval of more than 1/16 second between them, the time-interval will indeed be perceived as a duration, and the two impulses will be heard separately. But if the two impulses are heard again, with the duration shortened below 1/16 second, the sensation will be that of one single impulse; no definite pitch will be heard at all, just a single click! This is because the ear requires more than just two impulses to get a sense of a pitch. For repeated impulses spaced 1/1000 seconds apart, the ear needs around 12 in a row before a pitch is sensed. Backus gives, as reference for this experimental result, [Olson], p. 250.

Backus is referring to a relationship between the time-interval separating the impulses, on the one hand, and the number of successive impulses needed to define a frequency with reasonable certainty (i.e. enough to distinguish a "fundamental" frequency). Additionally, the human ear is not so precise a measuring device, and in general will need more than the theoretical minimum number of impulses to produce the sensation of a specific pitch.

This relationship and its limiting factor of unity are described more generally as an "uncertainty principle" of sound, in a direct analogy to the Heisenberg uncertainty principle and its limiting factor of Planck's Constant, in ([Gabor1946, 1947]). On a graph of time and frequency, the precision with which an isolated acoustical event, like a single impulse, can be located is limited mathematically; rather than a precise point, it can only be located in a rectangle of a minimum size depending on the representation and scaling. The limit is described by an inequality which is analogous to the inequality in one-dimensional static wave-mechanics that limits the accuracy of describing both the position and velocity of a sub-atomic particle-wave at a given instant.

Thus it actually makes no sense to speak of an event which is both completely specified as occurring at a precise instant of time, and with a precise single frequency. The more precisely you specify one attribute, the less precisely the other can be specified, according to this limiting factor.

Specifying a precise time instant, as in a single impulse, requires a broad spread of frequency components (thus an impulse click has the same frequency spectrum as "white noise"). Any real-world sound which has enough energy at a particular fundamental frequency or narrow band of frequencies to cause the sensation of a definite "pitch" has to occupy a certain minimum time-interval.

On the other hand, specifying a precise frequency, as in an ideal sine wave, with energy only at one discrete point in the frequency-spectrum, theoretically requires an infinitely long periodic signal; any interruption of the signal introduces energy in a wider band of frequency. Any real-world sound, which of course cannot last infinitely long with no variation, has energy at more than one point frequency-wise. And any real-world sound which lasts for a very short time is going to be ambiguous in pitch, i.e. is going to occupy a certain wide interval in the frequency domain. The sensation of "noise" as opposed to definite pitch is generally caused by wide intervals in the frequency domain.

But if we repair Stockhausen's assumptions so that we are dealing with a sufficiently long train of successive impulses to satisfy the mathematical and perceptual requirements of pitch-determination, his conclusion is basically valid. Frequencies above the threshold of roughly 16 cycles per second are perceived as pitches, while frequencies below the threshold are perceived as individual events in an overall rhythm.

Stockhausen proposes a "new morphology of musical time", which seems to mean several different things. One meaning is that all aspects of sound can be characterized by "order-relations in time", whatever that means. It is true that sound can be represented purely by successive measurements of amplitude at instants in time, although the usual representations of music involve some measurements of pitch, or frequency.

.Fourier's Theorem does state that the representation in time and the representation in frequency of an infinitely long signal are equivalent, that no information is lost by representing an infinite signal either as amplitude values at points in time, or as amplitude values at points in frequency. And the current practice of digitally sampling sound, then playing it back as pre-set samples, is an application of a pure time-domain representation.

Pure frequency information is most useful for representing continuous periodic sounds which do not vary in pitch, like sine waves. The pure electronic music done in the studios of the Cologne Radio station had used sine waves almost exclusively, and composers there had been optimistic about synthesizing interesting forms of musical sound purely through the combination of sine waves. But sounds in the real world have transient, or rapidly-varying, characteristics, which are only poorly modelled with sine waves (unless a very large number of sine waves is used, which is practically impossible to control). The initial optimism expressed in volume 1 of *Die Reihe*, for composition using only pure sine waves ([Goeyvaerts1955]) tapered off after Stockhausen's Electronic Etude I.

More interesting sounds were not so easily represented or synthesized with continuous, single-frequency sine waves. This led Stockhausen to his experiments with impulses and with the notion of time-domain representation of sound that he is trying to develop in his article.

Pure time-domain representations of musical sound require different tools than frequency representations. The most powerful models involve elements of both time and frequency in the representation of musical sound.

Gabor, in his derivations of the "uncertainty principle" for acoustical information, suggested that only a mixed representation which contained both time and frequency information could be truly useful as a representation of complex musical sounds. Gabor's choice for a representation was what he called a fundamental quantum of acoustical information. This quantum took the form of an "elementary signal", a fragment of a sinusoidal waveform enclosed in a Gaussian exponential amplitude envelope, with an overall duration as short as 10 - 20 milliseconds, at the edge of the duration threshold below which the sounds are too short to even be perceived by human ears.([Gabor1946])

Gabor's principle was noted by Iannis Xenakis, who referred to Gabor's elementary signals as "grains" of sound, and who proposed a method of sound synthesis involving the synthesis of each separate grain. ([Xenakis1971]). Composers and scientists have since developed powerful theories, including "wavelet analysis" ([Kronland-Martinet1991]), which capture information in mixed frequency and time representations, and have developed more elaborate systems for controlling digital synthesis of granular sound ([Truax1990b], [Roads1991]).

Gottfried Michael Koenig, who was Stockhausen's assistant in the studio during the composition of Kontakte, later becomes the artistic director of the Institute for Sonology, at the Hague, Netherlands. He develops a digital sound synthesis system called SSP in which the only data which can be specified, at the lowest level, is the amplitude of a certain time value. Thus he has carried Stockhausen's notion, that music can be represented solely as events in time, to its technical conclusion in the SSP system. ([Berg1980], p. 25).

We see that although Stockhausen is right under certain conditions, that musical signals can be completely represented purely in the time domain (again, this is the basis of digital "sampling"), his characterization is quite faulty on specific technical grounds. Furthermore, pure-time representations of musical signals are also not the most powerful ones available for sound analysis or synthesis. Few, if any, kinds of analyses or transformations of sound can be done without recourse to some kind of frequency information.

Backus continues his exposition of Stockhausen's flawed example with the other extreme. Supposing that a pure sine wave were given, instead of a train of finite impulses, with frequency 1000 cycles per second, and supposing that the frequency were gradually lowered to about 15 cycles per second, the sensation of sound would completely disappear! Instead of transforming into a sensation of rhythmic duration, our perception of the acoustic waves would vanish. A frequency would exist, and a duration between acoustic pressure maxima would exist, but our ears would simply lack the physical apparatus needed to detect them.

In order to produce the effect Stockhausen describes, the impulses would have to be finite (as they were in Cologne), perceptible in individual duration, and present in sufficient number to allow the ear to detect a pitch at the fast speeds. Then they would produce a sensation of duration if presented slowly enough, and would present a sensation of pitch if presented fast enough, as long as a sufficient number were heard to provide the definite pitch.

This phenomenon was noticed by others before Stockhausen. Even Ezra Pound the poet describes how the lowest notes of an organ could be discerned "not as a pitch but as a series of separate woof-woof's", and how "the percussion of the rhythm can enter the harmony exactly as another note would. It enters usually as a Bassus, a still deeper bassus; giving the main form to the sound" ([Pound1934], p. 301). Of course, in this same treatise on musical harmony and time, Pound also claims that his own personal copy of Mozart's "*Le Nozze di Figaro*" was marked, in Mozart's original handwriting, as "Presto, half note equals 84; Allegro, black equals 144"..... which tends to dilute the authority of his other claims....

Adriaan Fokker comments on the same example of Stockhausen's, of a pair of impulses slowing down to yield first a sensation of pitch, then one of duration. As a more clear example of the phenomenon, Fokker proposes a physical situation involving a steel ball, dropped from some height onto a horizontal marble slab. It falls perpendicularly and rebounds. The rebounds repeat themselves, but the time lapses between them diminish. The separate impacts of the ball form the sound of a roll, like a drum roll. The roll transmutes itself into a sound, a note of rising pitch, ... "We hear macrowhiles between the initial impacts. There are microwhiles between the impacts in the final state, which we no longer hear separately, perceiving a note instead..." ([Fokker1962], p. 69)

Fokker discusses the uncertainty principle of time vs. instantaneous frequency which we already mentioned. For N impulses or samples, the width of the frequency spectral band with nonzero energy will be (N+1)/N, which gradually converges towards unity (i.e., towards a single definite frequency) as N gets infinitely large To illustrate this, he gives an example of a double bass and a violin playing a passage in unison, within their respective ranges. The G on the bass, at 96 cycles per second, has no more than 12 vibrations in 1/8th second, so the frequency of the bass's tone in that interval has an uncertainty of (12+1)/12. Therefore the exact pitch of the bass in that 1/8th of a second is spread across an area covering 3/4 of a whole tone around 96 cycles per second. The G3 on the violin, however, at 384 cycles per second, makes 48 vibrations in this 1/8 second, with uncertainty of only 1/5 of a whole tone around 384 cycles per second, and the ear won't even notice this small uncertainty in the violin pitch.

Reiterating what Backus said, Fokker emphasizes that a sound making only one vibration in 1/1000 second, like the crack of a whip, does not relate a sensation of pitch corresponding to 1000 cycles per second, but the pitch uncertainty is evenly spread across an entire octave. Fokker concludes

"It is quite misleading to put a certain `while' in direct relation to a pitch. In the first place a single microwhile is not sufficient to determine a pitch, and in the second place, by increasing the length of the microwhile, the pitch is neither increasing nor rising, but sinking and decreasing." ([Fokker1962], p. 70)

Backus' next objection is to Stockhausen's term "subharmonic series of proportions", which is "another example of terms selected to impress rather than clarify." ([Backus1962], p. 18) This is merely a harmonic overtone series, based on the sub-division of a unit duration, so that successive higher partials refer to shorter and shorter durations, i.e. if 1 second is the fundamental duration, partials are found at 1/2 second, 1/3 second, 1/4 second, 1/5 second, etc.

Fokker again illustrates Stockhausen's point by giving the example of two double bass strings, one performing 3 vibrations against 4 of the other string. As they slow down below audio frequency ranges, below 16 cycles per second, a rhythmic sense is generated (because their individual vibrations are complex enough that they can still be detected as sort of individual impulses). There is a basic 12 units in one period, divided either in 3 bars of 4 units, or 4 bars of 3 units. Instead of starting the 3's and 4's simultaneously, an able pianist might shift the 3's so their first stroke is midway between the first and second of the 4's. Then the "metrum" would be 24 units in one overall period, either 3x8 or 4x6. ([Fokker1962], p. 71)

In a nasty jab, Backus says "His [Stockhausen's on p. 16] statement, `Even today, it is quite impossible to make a musician play a single 1/3 or 1/5 of a fundamental phase' ... makes one wonder about the calibre of the musicians of his acquaintance!" ([Backus1962], p. 18)

Hugh Davies, the British composer who soon went to work for Stockhausen in Cologne, responded to Backus by explaining that Stockhausen refers to the difficulty of playing only the first note of a triplet, followed immediately by only the first note of a quintuplet. While a good musician ought to be able to sub-divide a reasonable duration into 15 underlying units, so that the triplet element counts for 5 units and the quintuplet element counts for 3 units, in the two Stockhausen examples that Backus makes fun of, the underlying 15th-notes would only be 1/15 second long in one case and 1/105 second long in the other case. It is indeed doubtful that any musician could play such a passage accurately without extraordinarily unreasonable amounts of preparation for such a short fraction-of-a-second passage ([DaviesH1965], p.17)

Eventually, Backus tires of picking at specific problems:

"We conclude that Stockhausen's technical language is his own invention, using terms stolen from acoustics but without their proper acoustic meanings, and that the technical jargon he has developed is designed mostly to impress the reader and to hide the fact that he has only the most meager knowledge of acoustics." ([Backus1962], p. 20)

In retrospect, we feel that Backus has perhaps not picked up on the interesting musical ideas Stockhausen hints at, in his inability to get beyond the misuse of scientific jargon.

A second aspect of Stockhausen's "new morphology of musical time" is the notion of a unified compositional and structural approach to both the "macro" and "micro" time intervals (referred to by Stockhausen as "the sphere of duration" and the "sphere of pitch"). Traditionally in instrumental music, one composes a "score" in the macro-time domain, consisting of "notes", which are events performed on orchestral instruments. The internal structure of the notes is not precisely specified. Each note is, in turn, composed of events on the micro-time level. The advent of electronic music made it possible to think about controlling the micro-time level events, relating them to macro-time structures, and vice versa.

Concerning the general principle of composition as a unified approach to both the macrostructure and the microstructure of sound, Otto Laske, a noted researcher in compositional theory and artificial intelligence, writes

"It would be every composer's dream, to have at his/her disposition a task environment equally suited to modular composition in the micro- and macro-time domains, and thus to be able to dispose of the dichotomy of `orchestra' and `score' entirely. On closer scrutiny, to achieve a unification of the two time domains is a tall order. The task is nothing else but to unify a composer's decision-making in four temporal dimensions, of event-time, note-time, control-time, and audio-time. Of these, the first two make up score-time or macro-time, focusing on the `note' as a primitive, while the other two make up micro-time, focusing on the sample as primitive. While... macrotime is `fractal', microtime is `quantized', there being nothing much of aesthetic interest between note- and control-time, and between control-time and audio-time. For this reason, a strict analogy between these two sets of levels is hard, or impossible, to maintain, and information-hiding, in an object-oriented style or otherwise, is a crucial method for achieving their integration." ([Laske1990], p.132)

In the same journal issue, dedicated to compositional theory in the age of computer systems, H. Vaggione writes

"A digital sound object is always a composed one; it is composed music at the microtime level of samples. This fact in no way precludes, or contradicts, principles of macrotime structuring; rather, an interaction between all possible time scales is at the heart of the process by which a musical form comes into being.

"....To summarize, an object is transparent only if it is in an open state in which one can work on its internal structure. In order to manipulate the object as an autonomous entity, it must be closed under some name. The difference between a digital and an analog sound object lies in the fact that the analog one is a black box which can never be opened, while the digital object is open or closed, depending on the level at which the composer is operating." ([Vaggione1990, p. 211)

This shows the difficulty, or the impossibility, of Stockhausen's task of unifying the macro- and micro-time domains of musical sounds, working in the 1950's with primitive analog equipment, compared with the task today of working with digital sound objects, which can be either open or closed at the composer's will.

Barry Truax, through his work with granular digital synthesis over a number of years, writes of an insight, which most closely approximates Stockhausen's insight in his earlier attempt to construct musical sound from successions of single analog impulses:

"...The most dramatic paradigm shift I have encountered in my software development has been that involving granular synthesis. By shifting the base unit to the microtime domain, it challenges many if not all of our previous notions about sound synthesis and musical composition." ([Truax1990a], p. 230)

Truax mentions the threshold of approximately 50 milliseconds per event, or 20 per second, which is the boundary between separately perceivable events and micro-level phenomena which fuse together perceptually (this is close enough, given variations in measurement and in individual human perception, to Stockhausen's 1/16 second threshold). The technical term for this and related phenomena, like distinguishing between single and multiple melody lines or auditory signal sources, is "auditory stream formation". The classic reference on this topic is by Stephen McAdams and Albert Bregman:

"....In sequences where the tones follow one another in quick succession, effects are observed which indicate that the tones are not processed individually by the perception system. On the one hand, we find various types of mutual interaction between successive tones, such as forward and backward masking, loudness interactions and duration interactions. On the other hand, a kind of connection is found between the successive perceived tones....

"...Consider that a repetitive cycle of tones spread over a certain frequency range may be temporally coherent, or integrated, at a particular tempo. It is possible to gradually increase the tempo until certain tones group together into separate streams on the basis of frequency.... the faster the tempo, the greater the degree of breakdown or decomposition into narrow streams until ultimately every given frequency might be beating along in its own stream...

".... These findings indicate that the perceived complexity of a moment of sound is context-dependent.... Context may be supplied by a number of alternative organizations that compete for membership of elements not yet assigned. Timbre is a perceived property of a stream organization rather than the direct result of a particular waveform, and is thus context-dependent. In other words, two frequency components whose synchronous and harmonic relationships would cause them to fuse under isolated conditions may be perceived as separate sine tones if another organization presents stronger evidence that they belong to separate sequential streams."([McAdams1979], p. 25)

The last paragraph suggests that the perception of timbre, or tone quality, what Stockhausen refers to in his article as "formant rhythm", is a much more complicated subject than is possible to treat in any simple manner; certainly it is much more than a matter of simply combining pure sine waves at different frequencies and different amplitudes into complex "note mixtures" as was being attempted in the Cologne electronic music studio before Stockhausen began using impulse generators instead.

"...There are thus attentional limits in the ability of the auditory system to track a sequence of events. When events occur too quickly in succession, the system uses the various organizational rules discussed in this article to reorganize the events into smaller groups.... In the example where the fast sequence of tones merges into a

continuous `ripple', the auditory system is unable to successfully integrate all of the incoming information into a temporal structure and simplifies the situation by interpreting it as texture. Thus the auditory system, beyond certain tempi. may interpret the sequence as a single event and assign to it the texture or timbre created by its spectral and temporal characteristics." ([McAdams1979], pp. 28-42)

And thus we see that in spite of Backus' complete dismissal of Stockhausen's ideas because of the unclear presentation, acoustic scientists are now looking deeply into the phenomenon that Stockhausen is interested in, in the boundary between rhythm and pitch, between separate successive events and continuous texture.

The Serial System of Composition

"Serial music is doomed to the same fate as all previous sorts of music; at birth it already harbored the seeds of its own dissolution." ([Ligeti], p. 14)

Ideas inherited by Stockhausen, Pierre Boulez, Heri Pousseur, and other fellow composers in the 1950's, from earlier composers and teachers, like Arnold Schoenberg, Oliver Messiaen, and especially Anton von Webern, led to the style of compositional experimentation known in the literature as total, or integral, serialism. In ",,h*ow time passes...*" ([Stockhausen1957]), Stockhausen frequently speaks of "serial principles", or the application of the "serial system" to a given set of elements of musical material. Yet these principles, and this system, are never defined by him.

We deduce what he means by presenting some historical and theoretical background, culminating in the period of "total serialism" from 1949 -- 1953 ([Gibbs], p. 59) and the evolutionary aftermath, of which his article is an important landmark. The latter part of "*...how time passes...*" is devoted to finding a way of advancing beyond the limitations that this attempt at total control was found to impose on the music.

H.H. Stuckenschmidt, present at the West German premieres, in the early 1950's, of the important works in the "total serialist" or "pointillist" style, writes

"The impression made by all these works, even on a listener who had read the commentaries beforehand, was one of chaos. They put one in mind of multi-coloured oscillograms in which the traditional categories of melody and harmony had been suppressed in favour of shock effects of dynamics and timbre. The fact that these shock effects were organised according to pre-chosen series was only of theoretical interest." ([Stuckenschmidt], p. 214)

With nearly 20 years of perspective to reflect upon since that time, Stockhausen said this, in 1973:

"Most American composers identify serialism with historical time. And this is really childish. Because serialism means nothing but the following: rather than having everything based on periodic values in any parameter, what we do is use a set, a limited number of different values -- let's say 1, 2, 3, 4, 5, 6. And a series which is based on a scale of different values is simply the permutation of these individual steps in a given scale. We have two conditions to follow. In order to have a serial sequence of individual values -- whether it's pitch, timbre, duration, the size of objects, the color of eyes, whatever -- we need at the base to have a scale with equal steps. If we leave out certain steps of a scale we get a modal construction, as in old folk music. Chromatic music is the most neutral kind because it doesn't seem to belong to any particular style, it incorporates all the other scales within itself -- you use all the steps with equal importance. In serial composition, we use all the notes within a given scale of equidistant steps. It could be 5, 13, 15, or 32 to an octave - 32 is an important scale. But we have to use them, statistically speaking, with an equal number of appearances so that there's no predominance, no one tone becomes more important than the other. And we don't leave out notes. I make a series, a particular order of these scalar steps, and use this as a constructive basic principle for certain sections of a composition......

"...So serial thinking is something that's come into our consciousness and will be there forever: it's relativity and nothing else. It just says: Use all the components of any given number of elements, don't leave out individual elements, use them all with equal importance and try to find an equidistant scale so that certain steps are no larger than others. It's a spiritual and democratic attitude toward the world. The stars are organized in a serial way. Whenever you look at a certain star sign you find a limited number of elements with different

intervals. If we more thoroughly studied the distances and proportions of the stars we'd probably find certain relationships of multiples based on some logarithmic scale or whatever the scale may be." [Cott1973, p. 100]

Where did these ideas come from? To quote H.H. Stuckenschmidt:

"Schoenberg was one of the first musical theoreticians to discuss the properties of musical sound. In the 'Harmonielehre' of 1911 he distinguishes three properties: pitch, colour, and intensity. He makes the point that until then only pitch had been measured, and that little attempt had been made to measure or in any way organise colour or intensity." ([Stuckenschmidt1969], p. 52)

"... Serial techniques are essentially a systematic transference of Schoenberg's twelve-tone technique to elements of musical sound other than pitch. After frequency, the first element to which these techniques were seen to be suited was duration, i.e. the temporal dimension. Metre and rhythm are in fact the most important means apart from pitch of arranging musical sounds into organised shapes. A single note is not a musical element; it qualifies as a possible musical idea only when it joins company with other notes...." [ibid], p. 203

Schoenberg's twelve-tone system, of course, is his method of composition in which all twelve notes of the equal-tempered chromatic scale are given equal prominence, so that no rules of tonal harmony govern the choice of pitches in musical material. The twelve tones in this system nowadays are sometimes called "pitch classes", to emphasize that they each refer to all possible octave displacements of their particular chromatic scale degree (i.e. "C" refers to the entire class of all possible "C" notes on the piano), because their placement in different octave registers is not fixed until later.

The twelve pitch classes are arranged into a specified order called a "tone row" or "series", which is then used to generate all pitches of a given composition. The intent is to produce "... all the effects of a clear style, of a compact, lucid and comprehensive presentation of the musical idea." ([Schoenberg1975], quoted in [Gibbs] p.1) This clear style is to be contrasted, evidently, with the free atonality of Schoenberg's "Pierrot Lunaire" period, 1912 -- 1921 ([Stuckenschmidt], p. 91).

Variations of the initial row are obtained by the combinatorial permutations called "inversion", "retrograde", and "retrograde inversion". But once the basic row and its variations are established, the twelve-tone system of composition requires the composer to use the pitch classes in the order (with limited variations) given by these rules. And "[a] fundamental law of the twelve-tone method, which Schoenberg himself did not follow, is that no tones are to be repeated until the series is completed...." ([Gibbs], p. 4). This contradiction, between the fundamental law against repetition and the actual practice of the rule-maker himself, reminds us that music is definitely not a scientific discipline!

Schoenberg's twelve-tone method does not encompass all the parameters of the compositional process. Once a pitch class is chosen by the twelve-tone method, the choice of octave register, moment of onset, duration, timbre, even the choice of whether the note sounds alone or as part of a chord, are not specified by the method. Thus it is not a complete system of composition; structure and form have to come from elsewhere. And this is a shortcoming, in the eyes of Stockhausen and his generation in the 1950's, who wanted all parameters of a composition to flow from an initial set of governing principles, a more general series that could be applied in as many places in their music as they could find to apply it (the story of total serialism is, in a sense, a quest for musical parameters to control, and principles that may be used to control them) .

Oliver Messiaen, on the other hand, who numbered Stockhausen, Goeyvaerts, Boulez, and others including Xenakis among his composition students, does not employ the method of composing with all twelve tones of the chromatic scale. But he does set up rows of values for duration, mode of attack, and intensity in the *Modes de valeurs et d'intensites,* composed at Darmstadt in Cologne when he took the ailing Arnold Schoenberg's place at the annual summer institute ([Stuckenschmidt1969, p. 213). According to ([Gibbs1985], p. 5), concerning the Modes, "In this work, which is not serial, there are three strands of pitches, referred to as modes, each assigned specific registers, rhythms, dynamics, and attacks. This is the earliest instance of a work composed with such a strict application of parameterisation."

Messiaen had students study the talas of Indian music, repetitive rhythmic cycle structures, which he mentions in his *Technique de mon language musical* of 1944, along with his notion of "non-retrogradable rhythms" which are the same forwards and backwards. His organizational structures do not use every possible value of the given parameter, which is why they are considered, by him and by the serialists, as *modes*, rather than *series*. But his attempts to organize the non-pitch aspects of his compositions, and his suggestions that his pupils should carry this investigation further, influenced the serialists. Boulez's *Structures 1a* for piano, considered the cornerstone of the small collection of "total serialist" works, uses, as pitch material, the first one of Messiaen's pitch modes from the *Mode de valeurs et d'intensites* ([Gibbs1985], p. 9).

Schoenberg's pupil Anton von Webern, in his twelve-tone music, also to use more restricted principles of organization. In his Concerto for Nine Instruments of 1934, for example, all the pitch material is derived only from the three-note series B-Bb-D and its three mirror forms (retrograde, inversion, retrograde inversion). His systematic principles of organizing duration, attack, register, intensity, etc. actually give his music its form and structure, unlike Schoenberg's, and the serialists often write of Webern as their main source of inspiration.

Their attitude is evident in the following description. Herbert Eimert founded and directed the Electronic Music Studio at the radio station in Cologne, West Germany where Stockhausen produced his electronic music, and Eimert required that any work in his studios adhere to the serial system of composition ([Heikinheimo1972], p. 35, also [Stuckenschmidt1969], p. 183).

"Just as in dry climes the sculptural qualities of plants emerge, so does the interval-object win, in the brittle, hardened material-atmosphere of Webern, so high a degree of plasticity that its qualities are transformed into new music, perhaps the most important between the emancipation of the dissonance and musicians' discovery of the sinus-tone. With Webern's liquidation of the form-breeding, form-inflating ego-experience, music could again be grasped at its central point -- form: palpable, 'animated' form, such as Webern described, on a historical level, in the balanced, measured hovering of the voices in Ysaak's chant-settings." ([Eimert1955, p. 31)

Note Eimert's highly negative reference to the "form-breeding, form-inflating ego-experience". It seems that he is expressing strong emotions, in a reaction against emotionalism in music! In post-World War II Germany, perhaps the vehemence of the aversion to thematic form in music is added to by the desire to avoid the egos of the past. H.H. Stuckenschmidt later wrote "There is no doubt that the subjective factor that dominated music for so long in the name of 'emotional expressionism' is now close to extinction...." ([Stuckenschmidt1969, p. 178)

The admiration of Webern by serialists is not limited to Germans. Pierre Boulez also finds the systematic aspect of Webern's music attractive:

"Schoenberg employed the series as a smaller common denominator to assure the semantic unity of the work, but ... he organized language elements ... by a pre-existing rhetoric, not a serial one.....With Webern, ... the SOUND-CLARITY is achieved by the birth of structure out of the material ... the architecture of the work derives directly from the ordering of the series" ([Boulez1968], p. 274, as quoted in [Gibbs], p. 2).

Webern's atomization of the theme in his music is also important to Stockhausen:

*"... technically speaking, Webern reduced the themes and the motives to entities of only two sounds -- the interval. That was almost an atomization of the thematic concept: single ascending or descending intervals really were meant to replace an entire *theme* of classical music. So you have to listen very carefully to these two sound intervals in his music: they're the smallest possible entities of musical composition.... and that's why we could start with Webern's concept in order to go in a new direction....([Cott1973], p.224).*

The notion of thematic composition (except in its "atomized" form as treated by Webern) becomes something to avoid:

*"...All the early twelve-tone composers treated the series as a *theme* to be developed. They transposed it, added sounds, showed it in mirror form, but they always had a thematic concept. And composers like Boulez, Pousseur, and myself criticized this when we were young, pointing out that though the serial concept might have given birth to a completely new musical technique -- by getting rid of thematic composition -- composers like Schoenberg and Berg still couldn't get away from it. " ([Cott],p. 225)*

The implication is that Webern, unlike Schoenberg and Berg, has managed to "get away from" thematic composition. Instead, the concept of *proportions* assumes the position of greatest importance in the new serialist style:

"My greatest musical experience was my meeting with the music of Webern.... In Webern's work we realise for the first time the necessity of a system of proportion, in fact, for what we have called a standard. Webern's music is not serial, but it is on the way to being so in its limitation of itself to a single system of proportion in a composition. Webern was a twelve-note composer, but that is only of secondary importance. For him the important thing was the relationship of intervals. Fundamentally there is no great difference in the manner of composition between those of his works written before 1912 and his later twelve-note compositions...." ([Gredinger1955], p. 40)

Deriving structure from proportion is of even greater importance than Schoenberg's method of using twelve notes! Stockhausen even writes

"In reality, it is less interesting, when listening to series, that at some time or other all the chromatic steps should appear (this is true of every series), than which proportions are chosen between durations or notes, and how these proportions are distributed, how they are composed in relation to each other." ([Stockhausen1957], p. 23)

This concept of proportions is crucial to Stockhausen's new music:

*"What I said then was that in traditional music you always see the same object -- the theme or the motive -- in a different light, whereas in the new music there are always new objects in the *same* light. Do you understand? By the 'same light' I meant a set of proportions -- no matter what appeared in these proportions: the relationships became more important than what was being related. In this way you could constantly create new configurations by working with a series of proportions and, as we've said the other day, the proportions could be applied once to time, once to space. This created completely different musical figures, allowing us to move away from the thematic concept...."([Cott1973],p. 225)*

We see in this passage that Stockhausen is interested in setting up and then applying a series of fixed proportional relations (the "same musical light") successively to different musical parameters (the objects viewed in that same light). The hope is that the proportions themselves will be perceived by the audience, apart from the individual parameters that they are applied to (much as we can hear that two notes are separated by a frequency ratio of 2:1, an octave, regardless of their register or actual pitch). And this series of proportions, to be applied successively to different musical parameters (like pitch intervals, note durations, timbres, degrees of loudness, etc.) is what he tries to replace the thematic concept with, in his serial system. This is not an easy task, and the difficulty of finding the right way to apply proportions systematically to duration and rhythm is one of the themes of the article.

As an example of Stockhausen's use of generalized proportions, he wants to establish a series of proportional values (e.g. 4:3, 5:4, 2:1, etc.) which are then applied repeatedly starting from an initial pitch (say, A 440), to obtain a row of pitches, but are also applied repeatedly to an initial duration (say, 1 second) to obtain a row of different durations, to an initial loudness to obtain a row of different loudnesses, to an initial timbre or spatial location to obtain a row of different timbres or spatial locations, etc. and this is then used in the selection of the values given for each successive musical event in a composition.

Taken to its extreme in a brief period of experimentation in the early 1950's, application of the serial system to all parameters, in a total avoidance of thematic composition, came to be known as total, or integral, serialism. "Total serialism might be regarded as the use of a series and its permutations to generate all aspects of a musical composition. In a strict sense this is an impossibility as it [has] not been conclusively determined what constitute the elements of music. A more practical view would include the serialism of pitch, rhythm, and `other sound aspects (dynamics, tempo, timbre/attack/instrumentation), etc.' " [Gibbs1985], p. 1,)

According to Gibbs ([Gibbs1985], p. 4-5), three important concepts arise from total serialist thought: "First is the division of musical sound into separate parameters (pitch/frequency, rhythm/duration, loudness/intensity, etc.) .... This is evident from Stockhausen's examination of Webern's opus 24 (in Die Reihe) where he considers several sound attributes individually. This tendency towards the organization according to individual components of music was also encouraged by the availability of electronic musical equipment enabling composers to study the physical aspects of isolated sounds."

Gibbs' second concept, already mentioned earlier, is the avoidance of repetition (which, as we already pointed out, Schoenberg himself did not follow in his twelve-tone compositions!)....."A further aspect of this nonrepetition is the avoidance of periodicity. In serial composition, there is an interest in continuous renewal and variation of material."

"A third supposition in serial music is the use of precomposition in the creation of a musical work." (op. cit.) This means that a serial composer cannot sit down with a blank sheet of manuscript paper and begin writing down notes. First, some preliminary decisions must be made, and combinatory permutations and arrangements must be carried out as a consequence. The determination of exactly which elements to serialize, and in what manner, becomes an essential part of the compositional process, and the eventual filling in of the actual notes on the page is almost an anticlimax (at least, in the opinions of the critics of total serial music, whom we will hear from shortly).

Note that John Cage, in his chance music around the start of the 1950's, was already making similar pre-compositional decisions - what elements to subject to chance operations, and in what manner. Stockhausen claims that he first heard of John Cage's work from Dr. Warner Meyer-Eppler in 1955, after the period in question ([Cott1973], p. 68), and was therefore not affected by Cage quite yet. John Cage did perform *12' 55.677" for two pianists* and *Williams Mix*, two chance pieces, at the Donauschingen festival in October 1954 ([Stuckenschmidt1969], p. 218) In "...how time passes...", Cage's graphic notation is discussed, and Stockhausen also introduces a concept of performance variability which he does not wish to have confused with Cage's indeterminism. Pierre Boulez, apparently in a reference to Cage's music, wrote of "the adoption of a philosophy tinged with orientalism serving to mask fundamental weaknesses of compositional technique" ([Boulez1958], quoted in [Stuckenschmidt1969], p. 218).

The new music of proportions did not find favor everywhere, and the anointing of Webern as the patron saint of total serialism also was greeted with skepticism. Roger Sessions, after the peak of the total serialist period, when translations of the German journal Die Reihe had begun to circulate in the United States, cautions us:

"It is of course fashionable to regard Webern as the patron saint of the dominant contemporary trend, and to invoke his name as a rallying point for all that is most aggressively anti-traditional in contemporary music. As is so apt to be the case, there is a discrepancy at many points between Webern the symbol and Webern the actual figure. The latter, however individual his musical style, was of course as deeply rooted in the Viennese tradition as Schoenberg himself, and probably more narrowly; and without in any sense meaning to detract from his musical stature, one can say that he remained a loyal disciple to the extent of being more Schoenbergian than Schoenberg himself. Above all, and most important, he was a musician of the ripest culture, at once the most daring and the most realistic of artists..." ([Sessions1960], p. 166)

Peter Westergaard, in 1962, when the music and thoughts of the total serialists, at least according to their detractors, had reached the status of a "slogan", write:

"In one sense of the phrase a Beethoven symphony is 'totally organized'; that is, all the characteristics of sound that Beethoven could notate -- pitch class, register, timbre, duration, dynamics, etc. -- participate in, indeed are necessary to, the organization of the work as a whole. In the usual, slogan, sense of the phrase, only serial music is 'totally organized'; that is, only in serial music is the pattern formed by the variations within each separate characteristic easily analyzed and self-contained, only in serial music do the patterns within separate characteristics come from a common scheme. For in such music 'total organization' is to be achieved by the application of row procedures not only to pitch class but to other characteristics as well.

"Now the champions of serial music have often claimed that Webern's compositional techniques, albeit in a rudimentary or incomplete way, foreshadow their own. I must say that I have yet to find so primitive a procedure in any of Webern's music. For one thing, in Webern's music (as in Beethoven's) control of the interaction between characteristics of sound rather than pattern making within nonpitch characteristics is the principal consideration." ([Westergaard1962, p.107)

Roger Sessions also invokes Beethoven as a counter-example to the claim that only serial music is totally organized:

"The basic question of all is of course -- as is often the case -- 'Why?' The principle of so-called 'total organization' raises many questions and answers none, even in theory. First of all, what is being organized, and according to what criterion? Is it not rather a matter of organizing, not music itself, but various facets of music, each independently and on its own terms or at best according to a set of arbitrarily conceived and ultimately quite irrelevant rules of association? Was the music of Beethoven, or who you will, not totally organized in a sense that is much more real, since it is an organization of musical ideas and not of artificially abstracted elements?" ([Sessions1960], p. 169)

As a possible answer to Sessions' question "Why?", we have Herbert Eimert:

"To realise a structural web, Webern uses only the proved and the provable; everything else is rigorously excluded, and rightly, since it has no firm foundation. In intervals Webern discovered structure free from content, structure that is no longer the structure 'of something', that behaves much more as a pure phenomenon, something created -- a discovery that is paralleled by certain all-embracing intuitive appraisals peculiar to our time: that of Planck, for instance -- 'Whatever can be measured, must exist'. This seemingly insignificant and 'unobtrusive' phrase is the one by which, according to scientists, Planck exploded the scientific certainties of centuries. It could well be applied to the measuring-out of interval-distances and its musical consequences. But the objection to such parallels is justified; nor are they at all necesary, since, after all, their intersection at infinity lies beyond the sight of mortal men. As generalities they will unfailingly prove right, but in detail, here and now, in their insufficiently thought-out state, they give rise to more confusion than clarification...." ([Eimert1955], p. 32)

In the music of Webern, Eimert seems to have discovered an exciting principle which, he hopes, will explode the musical certainties of centuries (if we consider that his discussion of Max Planck in science is trying to make a literal analogy to the situation in music, that is). It appears that Sessions is holding up the "musical ideas" of Beethoven as being more real than the "artificially abstracted elements", which Eimert claims are the only elements which are "proved and provable". And it seems Eimert would dismiss Sessions' "musical ideas" as having "no firm foundation".

Eimert is actually referring to deeper structural principles, rather than mere linear ordering of random elements in the music. The following passage provides insight into the quest which we refer to as the period of total serialism.

"When we say that Webern organised more than the single dimension of pitch-levels, we should not imagine that, simply through drawing other strata of sound into his basic organisation, he arrived at a complete predetermination of the musical elements....In Webern, ordering applies far more to the basic elements; his deep centre is interval proportion, from which his entire organisational system unfolds as from a single point. To this process of measuring there are subordinate: the interval; the manifold reflections of the interval motif ('the same, yet always different'), and their mid-axial grouping which opens up the time-continuum as 'space'; symmetric organisation of harmony, which marks the entry to real 'sound-composition'; the variable profile given the notes according to their intensity, dynamics, and differentiated accentuation; in works for larger resources, the grouping of timbres (here the motivic-instrumental alterations of the sound are a fragmented legacy from 'Klangfarbenmelodie'); and finally the motivic use of rests, which in the de-thematised structural system no longer relieve tension but must be regarded as architectonic rests -- as it were, silent notes.

"In music, measurement is an operation on pre-arranged material; at the same time it is more than that; with the advent of 'proportioning' it is transformed directly into structure. The thinner, the leaner Webern's music becomes, through its compulsion to extreme refinement, the more structure is manifest in it. Thus, at the last, the 'ideal' of structure becomes the composer's inspiration -- this is one of the points closely preceding the practice of pointillist and electronic music, and at the same time the very heart of the musical process, completely protected from the dialectical assaults of the theorists of musical decadence since they have not even become aware of it as a target. The Wagnerian lament about 'the end' always characterizes the same situation; when music has been perfected it is at the same time, as the word indicates, an end. Those who uphold the well-entrenched views about 'no more progress in this direction' (an element in literary education for the past three generations) are entitled to their opinion, but it has no bearing on the business at hand. In this respect, not only

is there no difference between the 'aesthetic of musical impotence' of the 1920's and the current pronouncements on the 'senility' of the newest music -- there is a close and obvious connection." ([Eimert1955, p. 35)

Dare we say that, taking Eimert's last sentence out of context, total serialism might be in part a reaction against the accusation of "musical impotence"?

"Pointillist" music, to which Eimert refers here in the context of a simple pre-determination of musical elements, is a term he coined (actually "Punktuell" in German) in a 1953 lecture ([Stuckenschmidt1969], p. 213) . It refers to the early products of the total serialist experiment, in which the various parameters of music were indeed separately predetermined, each by a different series, and there was no underlying master system of proportion. Every note was an isolated "point" with no recognizable connection to any other note. It would appear that this is indeed the style which Sessions criticizes.

In a passage which suggests that his exploration of total organization was explicitly in the nature of an experiment, Pierre Boulez writes, of his *Structures 1a*,

"I wanted to use the potential of a given material to find out how far automatism in musical relationships would go, with individual invention appearing only in some very simple forms of dispositions -- in the matter of densities, for example." ([Boulez1976] p. 55, quoted in [Gibbs1985] p. 15)

Later, Boulez would criticize the strict results of his experiments:

"...one organizes rhythm, timbre, dynamics; everything is fodder for that monstrous polyvalent organization... What has led to this 'punctual' style? The justified rejection of thematicism. This was, however, to give a slightly naive solution to the problem of composition itself -- charging a simple hierarchy with substituting in the role formerly played by thematic relations. The structural plans renew themselves in parallel fashion identically; at each new pitch, a new duration affected by a new intensity. The perceptual variation -- on the surface -- has engendered a total absence of variation on a more general level." ([Boulez1976] p. 49, quoted in ([Gibbs1985] p. 6)

Other criticisms of pointillism abound. Since no form or structure is in evidence to the listener, the overall effect of the music, after its initial colorful impact, is limited:

"... however often you hear it, however familiar you are with the language of Webern and Debussy [and, presumably, the next generation, Stockhausen, Boulez, Pousseur, etc.], it is still difficult to perceive anything but a sequence of sonic eruptions, a succession of moments, which seek to convey something never before heard but only succeed in cancelling each other out.... It proves to be amazingly lacking in incident, apart from the completely elemental and basic incidents which are more like the cataclysms of nature than historical events. In short, it does not succeed in building up a pattern of growth...." ([Ruwet], p. 65)

Even worse is the reflection on the composer of such music:

"The composer who prepares his material mathematically beforehand deprives himself of the possibility of generally reviewing and thus fully controlling his material. An electronic computer could of course work out all the possible combinations of the four series [e.g. pitch, rhythm, intensity, timbre], but a composer has necessarily to make a selection from the gigantic sum of possibilities, and this selection will as before have to depend solely on his own subjective disposition. Total pre-determination, in other words, leads directly toa new irrationalism: the mathematical theorist's pipe-dream of ultra-precision is fulfilled only in irrationality." ([Stuckenschmidt1969, p. 210)

Stockhausen, too, recognizes the static quality characteristic of the pointillistic period music:

"The first compositions of electronic music and of `pointillist music' in general were extremely homogeneous in their sonority and their form. All the musical elements participated on an equal footing in the shaping process and all the properties of the notes were constantly renewed from one note to the next. Now when all the tonal properties are constantly changing at the same rate, and when no one property remains constant for a relatively long time, so that another property comes to predominate (for instance, longish note sequences in a high

register, then in a low register; or several notes remaining equally slow, then fast; or a note group played on the strings, then another on the winds; or first many loud notes, then many soft ones); when, rather, pitch, duration, timbre and intensity alter note for note (`point for point') then the music finally becomes static: it changes extremely fast so that one is always traversing the whole gamut of experience in the shortest time, and thus one gets into a state of suspension: the music `stands still'." ([Worner1973], p. 166)

However, Gyorgi Ligeti, who heard Stockhausen's music on the radio in Hungary in 1956, then barely escaped from the violent military crackdown there to join Stockhausen and the Darmstadt community in Cologne late one night ([Worner1973], p. 237), actually considers the static quality of this music to be a positive quality:

"Integral-serial composition was born under the sign of the totally static; there are few pieces in which this application is so extensively executed as in the Sonata for two pianos by Goeyvaerts -- the earliest example of total-serial music -- or in Boulez's Structure 1a for example...'Rigidity' and `static' are not meant as negative categories at all. Complete stillness may seem strange to one who is exclusively conditioned by our Western tradition, but this can form no basis for a value-judgment....This music is like hanging carpets of mighty oriental quietness, because the forces that drive on the flow of the form have been de-activated." ([Ligeti1958], p. 16)

And yet this same article by Ligeti is also the source for the quote with which we opened up this paper. He has negative things to say about the elementary application of serial principles to musical parameters.

"Now that hierarchical connections have been destroyed, regular metrical pulsations dispensed with, and durations, degrees of loudness, and timbres have been turned over to the tender mercies of serial distribution, it becomes increasingly difficult to achieve contrast. A flattening-out process has begun to absorb the whole musical form. The more integral the preformation of serial connections, the greater the entropy of the resulting structures; for -- in accordance with the relation of indeterminacy mentioned earlier -- the result of knitting together separate chains of connexions falls victim to automatism, in proportion to the degree of predetermination.

"The finer the network of operations with pre-ordered material, the higher the degree of levelling-out in the result. Total, consistent application of the serial process negates, in the end, serialism itself. There is really no basic difference between the results of automatism and the products of chance; total determinacy comes to be identical with total indeterminacy....

Ligeti believes that the hope (for serial music) lies in shifting serial control onto the more global categories that Stockhausen had already articulated in "*...how time passes...*" :

"*...The possibilities of organizing such an order and defining such musical characters are available where the weight of serial composition has been shifted onto the global categories that we mentioned earlier. The total form is serially guided, but the individual moments are, within given limits, left to the composer's discretion.*" *([Ligeti1958], p. 10)*

Stockhausen's need for a system of proportions that is perceivable as the fundamental organizational characteristic of his music is, in part, a reaction to these and other perceived shortcomings of the "pointillist" style which lacked such a characteristic. His "new morphology of musical time", as we shall see, is a practical outcome of this reaction.

Exegesis of "...how time passes..."

We now mention the topics covered in Stockhausen's article, in the order in which they appear. Following this section, we will return to some of them in more depth.

Beginning with the statement "Music consists of order-relationships in time..." [p. 10] Stockhausen introduces his concept of time-intervals between maxima or minima of acoustical sound-pressure waves, denoting them as "phases" (a misuse of an already-established word, which raises immediate objections from scientists [Fokker1962], [Backus1962]). He mentions that pitch and duration are really two different localized aspects of a common underlying phenomenon - we perceive a sound-event as a pitch if it occurs at a rate faster than around

16 cycles per second, but we perceive it as a duration if it occurs at a slower rate. (we will discuss some problems with this concept in the next section)

He discusses the traditional notation for durations, of note heads either divided from or multiplied by a fundamental unit which is generally assigned a metronomical tempo. If a whole note is taken as the fundamental, for example, then half notes are obtained by dividing a whole note unit by 2, quarter notes divide the whole unit by 4, etc. If an eighth note is taken as the fundamental, then quarter notes are obtained by multiplying the eighth note unit duration by 2, half notes multiply the eighth unit by 4, etc.

Stockhausen compares this system against the traditional notation for pitches, finding it lacking. Pitches can be named, in the chromatic scale, which are not whole number multiples or divisors of a fundamental unit. He looks at different ways that a scale of differing durations might be established. In passing, he suggests that a keyboard might be devised which would cover a scale of equally-tempered increasing durations, instead of increasing pitch values (we return to this duration-keyboard in the final section, where we also consider a proposal by Henry Cowell for a new rhythmic instrument).

Harmonic or "modal" scales are more easily established, as several examples show (which we treat in depth in a later section of this paper), but he is searching for a chromatic scale of duration, in order to apply his serial composition principles to it (we showed in the first section that his serial system requires an exhaustive scale of equally-spaced proportions in order to treat a given musical parameter, like duration). In fact, he criticizes the use of a harmonic series of durations in serial music up until that time as "stylistically inappropriate" [p. 14] for use in serial composition.

Following a criticism of poly-rhythmicality (also stylistically inappropriate), he brings out the notion of group structure, in which individual relationships among notes are lost in the texture of the whole group. This Group-structure is one of the tools he used, starting in *Gruppen*, to advance his serial system beyond the limits it reached in pointillism, where the parameters of each note were treated as isolated individual values and the music had an overall static effect.

At this point we are reminded of the words of Iannis Xenakis, also critical of this polyphonal serial music, but criticizing from a different angle, as an advocate of applying stochastic principles to musical parameters, rather than serial principles:

"Linear polyphony destroys itself by its very complexity; what one hears is in reality nothing but a mass of notes in various registers. The enormous complexity prevents the audience from following the intertwining of the lines and has as its macroscopic effect an irrational and fortuitous dispersion of sounds over the whole extent of the sonic spectrum. There is consequently a contradiction between the polyphonic linear system and the heard result, which is surface or mass. " ([Xenakis1971], p. 5)

Stockhausen points out that there is an inherent contradiction between the inner structure of continuous musical tones, which are composed of overtones related harmonically (the "harmonic scale of perception" [p. 20]), and their organization in 12-note series, which have no harmonic or any other hierarichal structure (the "chromatic scale of perception" [p.20]). The introduction of this contradiction with the 12-tone compositional technique is, he says, what Schoenberg really meant by the "emancipation of the fundamental tone" [p. 20]. We shall have more to say about this issue too, in a later section of this paper.

He proposes that this contradiction should also be introduced into the sphere of rhythm -- that the internal structure of a rhythmic section, corresponding to a single complex tone in the sphere of pitch, should be considered separately from its placement among other rhythmic sections in a rhythmic series, corresponding to the placement of a single tone somewhere in a 12-tone row. This would allow the natural harmonic structure of related rhythmical sub-divisions to unfold, within an individual rhythmic unit, but would also allow his serial system to treat that entire harmonic structure as a single unit, to be placed before, after, or alongside other different units in accordance with the proportional series governing the macrostructure of the piece.

Then he proposes a system of equally-tempered "fundamental durations" ([p. 22]), analogous to the equal temperament of fundamental pitches. And finally he is ready for the application of the serial system to a set of fundamental durations, much as he applies it to a set of fundamental pitches (each with its own differing harmonic overtone series and resultant timbre). He works out an example which soon grows rather complicated, involving the variable overlap of different successive "groups of fundamental durations" [p. 24]. Adrian Fokker ([Fokker1962]) attempts to clarify this example, taken from the piece *Gruppen*, which we return to in detail later.

Continuing with his example, once he has applied the serial system to the set of fundamental durations, he discusses how one might use it again to choose the internal rhythm inside that duration, which is like choosing a timbre by constructing an overtone series on a fundamental pitch.

Furthermore, if different fundamental durations are present at the same time in a piece of music, they may require different, spatially separated groups of instruments, each with their own conductor, in order to be accurately performed (this is one of the main reasons why there are three orchestras in *Gruppen* and, later, four orchestras in *Carre*).

He mentions another contradiction, between "material and method, i.e. .... between instrumental music and serial music" [p. 29]. The composer who seeks to apply the strict serial method to musical durations finds that the written music which results is impossible for humans to play accurately! The choice then is to either "completely renounce instrumental music, and compose only electronic music" [p. 29], or else "seek a completely different path in composing for instruments, through a conception of musical time that is absolutely new". And he proceeds to explain how this might be done.

Not everyone would agree that the goal of completely notating events down to the smallest level of control is even worth pursuing in the first place:

*".... What appears musically precise or specific is in fact not. The seeming exactitude of many aspects of musical notation makes many composers think that if only a reliable means can be found consistently to represent this 'exactitude' synthetically in sound, human misrepresentations of compositions will be no more. But when one comes to commit oneself electronically to a 'precise' event, never after its realization again to be inflected by interpretation, it develops that what one though was precisely specified in conception was really only generally outlined. It is gratuitous to speak of creating circumstances in which composers can realize every musical event 'exactly' as they want, since no composer ever *has* known exactly how he wants it, and since even the most exact vision of the event at the moment of realization will alter with time."*

"Write a note for flute: no matter how well you know the note, a player can vary it within what you thought were minima. Write a short note: no matter how exact its length may seem in your mind, when you come to perform it, you will find a range of easily perceived variations that lies within acceptable limits. These are the lessons and resources of live performance. They point to the fact that even the most detailed and exact score is actually a set of generalities. They reveal the staggering size of the musical universe, the capacity to perceive which is one of man's rarest treasures. Even the smallest event in a musical fabric, an event of which there will be thousands of similar others in a single work, contains within it an infinity of variation and capacity for interpretation. This variation is not merely at the margins of the perceivable but contributes to the central range of meanings borne by the work." (Charles Wuorinen, in [Schwartz1973], p. 256)

Instead of rigidly precise durational values, human performances always involve some amount of variation. Stockhausen discusses what he calls "time-fields" [p. 30] with a precise durational value given at the center, and a certain bandwidth of leeway to either side, in which repeated performances may vary. That is, the field is a delimited area of possibility, in which the actual value of a given performance will take a certain value.

He suggests that the more precisely detailed that musical events are notated, the less precise their actual performance by musicians is. "...the more complicated the way in which a time-value was indicated, the less sure the performer was about when it should begin and end." ([p. 30])

He gives an example of four different ways to notate the same events (durations in the relationship of 4/3 to 2/3 of a larger fundamental duration) and predicts the relative accuracy of performance for the different notated versions. (in this brief example, the version he feels will be performed most accurately is written with larger note-heads, i.e. quarter notes, while the version he feels will be least accurate is written with sixteenth notes -- one wonders whether this leads to a simple generalization, namely that music written with quarter notes is easier to read than the same music rewritten in sixteenth notes? but such a simple conclusion would preclude the lengthy investigation which follows!) He proposes experiments, having instrumentalists perform differently-notated versions of the same complex passages, tape recording the performances, and analyzing the precise durational values found, to develop a scale of increasing and decreasing performance variability.

The goal, as always, is to find a parameter to which he can apply the serial system. So if he can devise an equally-spaced scale of performance variability, including all possible values, perhaps based on the way that a given group of musical events is notated differently, he can then choose an ordered series from the scale. And this would open the way to move serial music out of the realm of precisely specifying individual events, into the realm of specifying the overall limits of statistical collections of randomly varying events. Additionally, this points the way to new possibilities in instrumental music, which are not present in pure electronic music, in which there are no performers and hence no variability factors to work with.

Stockhausen distinguishes between performance variability which comes about merely by chance, due to the complex nature of the notation in a piece, and variability which has been precisely specified in its statistical parameters, i.e. as deliberately composed Variable form (even though the parameters like exact onset time, duration, precise pitch, etc. of the individual events themselves, by definition, even the number of events in a collection, are not specified by the composer of the variable form).

He is still depending on the human performer to supply the variability (this is true in both the "chance" situation and in the precisely specified variability situation) rather than the use of stochastic processes ([Xenakis1971]) for the generation of event parameters. It is the limitation of a human performer, rather than an evaluation of a random variable in a Poisson probability distribution, which Stockhausen is interested in. In fact, the music written by Xenakis for real performers, notated from instantiations of stochastic variables, would fall under Stockhausen's first category, of music which is variable in performance due to the performer's difficulty in following the notation's precisely detailed instructions!

Stockhausen examines the possible ways of presenting a scale of, and serially choosing from, different field-sizes of variability, in the sphere of duration. In the case where several separated orchestras are each playing their own different tempi, i.e. in *Gruppen*, the longer they play, the more likely it is that they will get out of step. Thus the variability field increases with the length of the segment of music. But no discrete steps can be isolated in this increasing process, so it is of no use to his serial system; the displacement, the amount that they are out-of-step with each other, may come gradually, continuously.

If the different orchestras are not playing fixed tempi. but are rather speeding up or slowing down individually, the situation is more complicated. Here, Stockhausen devises a discrete scale in which, for example, the number 0 refers to the situation where all the orchestras have constant tempi; 1 is the situation where all tempi are constant except for one which is varying, 2 is where two tempi are varying, and so on. This still allows him to apply the serial system to these higher-level, qualitative numbers - critics like Backus and Fokker wonder why he is so obsessed with this "mystical belief in numerology as the fundamental basis for music" ([Backus, p.20]). We will see later that Stockhausen continued to use this generalized, qualitative serial system, using it in the pre-compositional plans for *Kontakte* in denoting the movements of sounds among groups of loudspeakers.

Stockhausen discusses further the "statistical composition " [p. 32] of fields which contain events, but the events are not precisely specified, and are not even always separately perceptible. When the individual events in a mass-structure are separately perceptible, then the statistical quality falls away; the statistical quality depends on crowding in a short period of time ("Mass-structure means, then, merely the momentary opacity of a group" [p. 32]). We will compare Iannis Xenakis's statistical approach with this later.

Now he presents the `pointillistic' style, of precisely specifying all the parameters for each sound event , as merely a special case of the mass-structure in which all variability factors are zero, and the event is fixed compositionally as a point rather than a field (note that the performer still may not be totally accurate in the performance, so there will be some variability anyway, but it is of the kind he calls "chance" rather than of the composed kind).

Returning to his discussion of how different degrees of notational complexity, each representing the same sound-event to be performed, lead to differing amounts of variability, he wishes to devise a suitable notation for the variabilities (and of course, he will want an equally-spaced scale, in order to apply the serial system).

First, as an example of how NOT to do this notation, he discusses John Cage's graphic time notation [p. 33] in which time is represented by exact horizontal measurements on the printed page (i.e., say, 1 centimeter of horizontal space equals exactly one second in time). The vertical axis represents pitch, in the usual musical staff. A sound-event composed to begin five seconds into the piece, of exactly one second in duration, at pitch A4 would be represented by a horizontal line beginning exactly five centimeters from the left edge, and exactly one centimeter in length at the A4 position on the G clef.

Stockhausen feels that this notation leads to much less certainty, in actual performance, of exactly where the duration begins and ends, even though the notation appears to be more precise than that using traditional note heads and stems. The reason is that the performer's eyes have to scan the horizontal line segment, measure its length, and translate that into a performance of a certain duration. No matter how long or short the line segment, the same interpretative procedure must be followed. Consequently, the variability factor is the same (according to Stockhausen [p. 33]) no matter whether the composed event is long or short - that is, there is imprecision in executing the onset moment of the event, and imprecision in executing the end moment of the event. On the other hand, with more traditional notation using note heads and stems, the performer's eye gets to count individual notes, which each have a known duration in relation to an underlying metrical time unit, or sub-divide the notes, again with an underlying metrical time unit available to assist in accuracy.

Cage has done away with all notions of proportionality in time-relationships, since there are no notes to be grouped or sub-divided. Therefore, Stockhausen feels, Cage has made all time proportions less distinct, and the result is a continual disorientation in time. Rather than a feeling of timelessness (remember, Stockhausen's investigation is trying to determine how to get away from the precise specification of time, to allow a variability that is nevertheless precisely notated in its extent, which might indeed produce a sensation of timelessness in the listener, but he is still very interested in preserving the sense of relative proportions among different time intervals, which is required by his serial system), Stockhausen feels that this leads to a sense that time is bound to one plane (literally, the horizontal plane on the paper) and therefore is equally present at each moment. And of course this is no use to him and the serial system since it cannot be ordered in degrees of increasing or decreasing performance variability.

Stockhausen returns again to his search for a possible notation of variability in time. He wishes to devise a scale of variable-field sizes which can be serially treated, yet which contain continuous time inside them, yielding qualitative rather than quantitative control. He looks for examples of variable time in traditional notation [p. 34].

He discusses the `grace-note'. In a group of grace notes, to be played `as fast as possible', the individual notes are usually not identical in duration or evenly spaced in onset time, and this is an example of what he is looking for. The speed with which the individual notes can be played (he uses the piano keyboard as his example) depends on their location on the keyboard, relative to each other. Thus the movements of the pianist's arm, which are different for each grace note in the group, is one factor which determines the individual variability of each note (but the traditional composer does not notate the arm movements! instead, they notate the individual grace notes). The reaction time of different performers is another factor, and so is the resonant character of the room in which the performance is given, because the notes must be played slower to remain clearly distinct in a more reverberant hall. But these latter factors are constant across the whole group of grace notes, and thus play no part in Stockhausen's desired notation, while the arm movements are different for each note, and thus are a potential source of information to be notated by him.

He speculates that a series of variable field-sizes would correspond to a series of actions taking various lengths of time, much as the pianist's arm takes various lengths of time to reach the different members of a group of grace notes, and therefore causes the grace notes to occur at varying lengths of time. He might specify a variable number of preparatory movements before each note can be struck, for example (and a serial series of differing proportions among the movement-lengths could be established). The duration of `rests' [p. 34] depend for their onset on how a sound decays to silence, and for their conclusion on how soon the performer is prepared to play the next note. This preparation can be mental if the musical notation is esoteric, or it can be practical depending on the physical properties of the instrument (i.e., the hammer which strikes a piano string takes a finite amount of time to recover before it is ready to strike the note again, and a string player needs a certain time to re-position the bow for the next attack).

So he is interested in a way of making an equally-spaced scale out of the variable action-times needed for producing different sound-events. He mentions John Cage again, who is not interested in constructing such a scale, but who has given elaborate instructions, on occasion, which require appreciable amounts of time to carry out a musical action. The example given is "engage the right-hand pedal, attack the note staccato and immediately allow the pedal to spring just so far back that the note goes on sounding softly as an echo" ([p. 35]) and the presumption is that Stockhausen is interested in using such an instruction as perhaps one of the larger values in a proportional scale of action-times. (*Klavierstucke XI* is where he implemented such ideas)

The next situation he examines (from *Zeitmasse*) involves a woodwind player, who must pause to breathe now and then. This gives a natural grouping to the notes that are played in one breath, and Stockhausen considers the relationship of the variability of the overall breath-group with the variability of each individual note within the breath-group.

The duration of the breath actually depends on the register, density, and loudness of the notes to be played in it (ignoring the physiological factors of the musician). "The lower and louder the notes, and the fewer sustained notes there are to play, the shorter the duration of the breath is." [p. 35] Supposing that the tempo indication "as slow as possible" is given, the individual note-durations must be distributed over as long a breath-duration as possible. So the length of the breath, overall, determines how much time is available for distributing among the individual note-durations, but the breath-duration depends on the register, density, and intensity of the individual notes. The composer can specify that the individual notes are each to take a fixed proportion of the overall breath length, which can vary, or they can allow variability of the proportion, of the overall breath length, that each individual note can take (again, with the overall breath length also allowed to vary). In this second case, then, there are two levels of variability, the breath length and the individual note length, which are interdependent.

He proceeds to discuss the overall structure of a piece (*Klavierstucke XI*), which can also be composed in variable form. In his example, the duration of each group of notes is not fixed in advance, and neither is the order in which the groups are to be performed. At the time of performance, at the conclusion of one group of notes (which has been played with a certain variation in duration), the duration of the next group is determined, based on the some ratio taken with respect to the duration of the previous group.

The overall form of this piece, and the field of variability that contains it as a whole, "will become clearer, naturally, if it can be compared with that of other pieces in a cycle, or, above all, when it is played several times in succession." [p. 36] Thus this piece actually doesn't fully exist in any single rendition; the form can only be appreciated by experiencing several versions and noting the common tendencies shared by all.

Stockhausen explains why he doesn't consider this kind of piece to be an invitation to improvisation on the part of the performer. The fields of variability, with their fixed degrees of freedom, are "no occasion to invent something in addition to the composed structure". [p. 37] Instead, we experience time-proportions which can only arise through the performer's physical actions, where previously, time-proportions were usually notated in absoute time as counted on the clock or as counted against metrical units.

No longer can one look at the time-notation in the score, and check the `rightness' of a given realization against it. "In a field-composition, the parts of the score in which actions are notated give no information at all about the measurement of time-proportions -- the latter come into existence only at the moment when they are realised in sound, when they are played. In this case, the `rightness' of a realisation is checked against itself; tested, that is, in order to find out whether the action-times in the moment of playing stand in an organic relationship to the sound-times to be produced...." [p. 37]

He suggests that one could even interpret this situation as one where the performer, rather than "mechanically quantifying durations that conflict with the regularity of metronomic time" [p. 37], is actually precisely measuring and interpreting sensory information. That is, in fulfilling instructions like "play as fast as possible", the performer relies precisely on their own feeling of whether the notes are as fast as possible yet, while still sounding clearly and distinctly enough, rather than relying on some vague quantification of a variable duration on the clock. And the variable duration is then a precise consequence of the sensory information.

Finally, the notion of degrees of freedom can be applied to the act of composition itself -- the composer chooses from a range, with one extreme being total pre-determination of all durational quantities, and the other extreme being "chance" determinations, with the ability to select an intermediate value (presumably, in application of his usual serial principles....) before proceeding with the pre-compositional sketches that then determine the composition itself.

Having completed his study of variable field-composition in the sphere of durations, he now presents some important consequences in the sphere of pitches, i.e. in composing works for variable-pitch using this system of fields with degrees of freedom.

Since pitch would have to be continuously variable, only instruments capable of non-fixed scales could be used (no pianos, for example). The case of fixed-pitches would be a special case, where the field-size was zero, leaving no room for variation. Just as in the case of durations, the particular pitches could result from specific physical actions with variable distance required to accomplish them on the instrument, or they could also be determined by breaking up a group into parts and then instantiating specific pitches within the parts (this was done for durations in "Zietmasse", involving the number and length of notes possible to be played in one single breath of a wind instrument).

Then, too, the case where the pitch remained constant over the duration of a note would be the exception rather than the rule, for in the general case, the pitch would be the result of individual "phases", single cycles, which would not be exactly periodic, but would also be varying within specified limits. Thus a new instrument would have to be designed, allowing continuous variation between definite pitch and noise, and continuous variation of the fundamental frequency, as well as harmonic spectrum (we consider this again in the section where we compare Henry Cowell's new musical instrument, the Rhythmicon).

His final comments concern yet another contradiction, this time "between, on the one hand, a material that has become useless -- instruments that have become useless -- and, on the other, our compositional conception." Instead of dwelling on this contradiction, he has apparently chosen to reconcile himself with a new concept of musical time.

It seems to us that he is actually admitting defeat, or at least compromising, by modifying his compositional conception of total serial organization. Instead of the lofty goal of total control over all musical parameters, he has admitted that this is impossible, or at least leads to uninteresting results and is therefore useless. Instead, he now wishes to control only higher-level qualitative parameters with his system, in order to resolve the contradiction and continue composing for real instruments.

And it is clear tht he does not really regard traditional instruments as useless - otherwise why would he have continued composing for them? In fact, as ([Heikinheimo1972]) points out, once he completed the tape part for *Kontakte*, he never again composed a piece of pure studio electronic music; in all future electronic works, he included real instruments among the sound sources.

"Useless", indeed!

Specific Examples

In this section we discuss several of Stockhausen's examples in greater detail, including one which Adriaan Fokker has given some corrections for. First, we discuss Stockhausen's examples on his page 11 summarized here in Table 1, on his page 13 and 16 summarized here in Table 2, and on his page 21 summarized here in our Table 3. Basically, Stockhausen shows various ways one might try to derive a complete scale of equally spaced durations, in correspondence with the equal tempered chromatic pitch class scale; he goes through several unsatisfactory derivations.

After that, we discuss his further examples, in which he does successfully establish a chromatic scale of durations, but at a costly price: his abandonment of serial principles of total quantitative organization of musical parameters, and his acceptance of variable factors out of the composer's control. This revelation leads his music out of the contradiction inherent in the music of total serialism. The final example we consider seems, at least to Fokker, to reinforce the impression that Stockhausen is a musician and not a scientist.

The first example begins with a consideration of whether it is feasible to construct scales of durations, analogous to the scales we construct in the sphere of pitch. Taking a unit duration of one second as the fundamental, Stockhausen refers to traditional notation of duration, in which a smallest unit is given as an eighth-note head, and other durations are whole-number multiples, i.e. quarter note, half note, whole note. The smallest unit either remains indefinite, or else is metronomically defined (i.e., MM 1/8th note = 60, meaning 1/60 minute, or 1 second).

"It is quite clear that a metronome does not determine durations, but a tempo. It presupposes a series of repeating beats. Therefore it does not define a duration, but a frequency, in cycles per minute. The notation should not be M = 60; but: frequency = 60 cycles per minute (f = 60/M), What is the origin of this muddling of concepts: phase, period, frequency?" ([Fokker1962, p. 69)

In the light of Fokker's suggestion, to clarify the issues as much as possible, we will refer to frequency or duration as appropriate, using MM metronome markings only when explicitly needed in the musical context. Therefore, even though Stockhausen writes MM = 60, we consider "duration = 1 second" when it makes things clearer.

Table 1

Column 0	Column 1	Column 2	Column 3
	From p.11	From p.11	From p. 11
Chromatic number (pitch name)	Mult. by unit duration	Division of Largest unit	Constant 2/1 proportion
13 (A octave)	13 sec.	1/13 sec.	8192 units
12 (Gsharp)	12 sec.	1/12 sec.	4096 units
11 (G)	11 sec.	1/11 sec.	2048 units
10 (Fsharp)	10 sec.	1/10 sec.	1024 units
9 (F)	9 sec.	1/9 sec.	512 units
8 (E)	8 sec.	1/8 sec.	256 units
7 (Dsharp)	7 sec.	1/7 sec.	128 units
6 (D)	6 sec.	1/6 sec.	64 units
5 (Csharp)	5 sec.	1/5 sec.	32 units
4 (C)	4 sec.	1/4 sec.	16 units
3 (B)	3 sec.	1/3 sec.	8 units
2 (Asharp)	2 sec.	1/2 sec.	4 units
1 (A)	1 sec.	1 sec.	2 units

Column 1 of Table 1 shows the actual durations that result, which form a harmonic overtone series. Note that this method is equivalent to multiplication of the chromatic scale number by the fundamental unit duration. That is, the fifth scale degree has the duration of five seconds. Although he doesn't specifically mention it, the ratio of successive scale degrees is not constant. The ratio of the second to the first scale degree is 2:1, the ratio of the third to the second scale degree is 3:2, and so on (he mentions, in the context of the second example immediately following this one, that a non-constant ratio is unsatisfactory).

His second example, yielding the results in Column 2 of Table 1, is derived by taking a largest duration and sub-dividing it for each successive partial harmonic. This would correspond to a metronome marking assigning MM whole note = 60, or one second for a whole note, with a half note = 1/2 second, quarter note = 1/4 second, etc. Note that this corresponds to multiplying by the reciprocal of the chromatic note number, i.e. the fifth scale degree has the duration of 1/5 second. Also note that the durations get shorter as the scale degree goes higher. This also results in a series of durations with unequal ratios between the successive pairs, which he doesn't like, because his serial principles need equal proportions between the elements of his scale. The ratio between the second and first scale degrees is (1/2):1, which is the same as 1:2. The ratio between the third and second scale degrees is (1/3):(1/2) which is the same as 2:3, different than the first ratio, for example. The ratio between the 12th and 11th scale degrees is (1/12):(1/11) which is the same as 11/12, only slightly less than unity. The ratios between successive scale degrees form the sequence [1:2, 2:3, 3:4, 4:5, ...], which approaches but never quite reaches the limit of unity as the scale degree increases infinitely high.

Next, he tries making a scale of durations which will meet his needs and exhibit constant proportions, i.e. equal ratios between all pairs of successive scale degrees, by using logarithmic relationships. Thus a constant proportional ratio (he uses 2:1 for this example) must be used to derive each next duration. The fundamental is given by him as 2 unspecified units. We don't know why he starts at

21 = 2 units instead of at 20 = 1 unit, which would be more natural. Each successive scale degree is formed by taking the exponential power of 2 raised to the scale degree. Column 3 of Table 1 shows the result, which differs greatly from the duration series of Columns 1 and 2 in its form. The highest value shown, the next "octave", is a whopping 8192 units.

One would have to fill in a metronomical duration value for the unspecified units, and he warns that this value cannot be made very small because of the limits of our perceptual facility to distinguish between durations which differ by the ratio of 15:16. He points out that in the sphere of pitch, an equal-tempered semitone corresponds roughly to a pure frequency ratio (interval) of 15:16 Although his remarks are confusing in the context of the example given, we interpret them as pointing out that we can't make the fundamental duration too small a metronomical unit, because any groupings of multiple quantities of these small units will be too hard to distinguish, due to their small overall length. That is, if we made the fundamental unit 1/100 of a second, we couldn't distinguish a grouping of two units (2/100 second) from a grouping of three units (3/100 second) very easily. This is true regardless of how the duration scale itself is chosen, proportionally, which is why his comments are confusing.

On the other hand, the metronomical unit cannot be chosen too large, because of the enormous ratio between the upper scale degrees and the fundamental. Presumably, if they are to actually be used as note durations in a real piece of music, there are practical limits to the longest acceptable duration. For example, if the metronomical unit of 1 second were chosen for the fundamental, then the first "octave", the 13th scale degree, would have a duration of 8192 seconds, which is more than two and 1/4 hours! Even the 6th scale degree would have a duration of 64 seconds, more than a minute. Clearly the fundamental duration of this scale must be chosen very small, and then we run into the perceptual limit mentioned in the previous paragraph at the low end of the time scale. So the vast range of durations in this scale, the way it grows geometrically, is a problem.

Table 2

Column 0	Column 1	Column 2
	From p. 13	From p. 16
Chromatic no. (pitch name)	Smaller mult. by unit duration	Smaller division of largest unit
13 (A octave)	1/154 sec.	1/1300 sec.
12 (Gsharp)	1/167 (166?)	1/1200 sec.
11 (G)	1/182 sec.	1/1100 sec.
10 (Fsharp)	1/200 sec.	1/1000 sec.
9 (F)	1/222 sec.	1/900 sec.
8 (E)	1/250 sec.	1/800 sec.
7 (Dsharp)	1/286 sec.	1/700 sec.
6 (D)	1/333 sec.	1/600 sec.
5 (Csharp)	1/400 sec.	1/500 sec.
4 (C)	1/500 sec.	1/400 sec.
3 (B)	1/666 sec.	1/300 sec.
2 (Asharp)	1/1000 sec.	1/200 sec.
1 (A)	1/2000 sec.	1/100 sec.

Next (see Column 1 of Table 2), he tries multiplying the chromatic scale degree by a smallest durational unit again. Apparently this is what was done previously in serial music when scales were established for durations, in what he now considers a naive attempt to mirror, in the sphere of duration, the scales of equal-tempered frequencies in the sphere of pitch. This time, his fundamental unit duration is a small fraction (1/2000 second) instead of the 1 second he used last time. And this fraction, when multiplied by the chromatic number of each successive chromatic step, yields durations which approach closer and closer to the upper limit of unity (1 second), unlike those in in Column 1 which will keep increasing unboundedly forever. Thus the overall range of durations is limited, which avoids the problem in the previous example (Column 3 of Table 1). Moreover, the resultant frequencies, assuming that the durations are each one cycle of continuous sound-waves, are in the audio range, producing the sensation of pitch rather than rhythm.

This resultant series in Column 1 of Table 2 is what Stockhausen now calls a "sub-harmonic series of proportions" (the term which, as we already pointed out in the previous section, physicist Backus particularly singled out as unnecessary jargon). The ratios between successive scale degrees is still the same as it was in Column 1, in spite of the change in fundamental from 1 second to 1/200 second. The ratios still go [2:1, 3:2, 4:3, 5:4, ...].

He plots the successive durations as pitches on a treble clef (our durational notation makes it easier to see than his metronomical units, because the fundamental frequency is 2000 cycles per second, the first partial "undertone" is 1000 cycles per second, the third is 666 cycles per second, and so on, with the 13th partial, or the first "octave", being 154 cycles per second). He finds that the pitches form a mode, rather than a chromatic scale, in which not all pitches are present. He comments that this (durations arranged in a mode) was used by Messiaen in his piano study (*Modes de valeurs et d'intensites*).

He points to the mistaken use of such a mode of durational values, as if it corresponded to a chromatic scale of pitches when it actually corresponds to a mode, and remarks that this led to major contradictions in previous serial music. The extremely long durations, when occurring with equal frequency as the extremely short durations, tended to predominate overwhelmingly in the absolute length of the piece. Plus, the proportions were uneven, and "hierarchically preordained" which is unacceptable in his serial system.

We already commented that this example is much more constrained in its range of values (from 1/2000 second to 1/154 second in its first "octave", converging towards unity as a limit) than the previous example (which ranged on up to 8192 units already in the first octave, with no upper limit). Note that as long as the metronomical unit assigned to the fundamental duration is less than one second, all the chromatic scale degrees will also be less than one second, and will tend towards unity (one second) as their upper limit.

A larger choice of metronomical unit for the fundamental duration, bringing it out of the audio frequency range and into the sphere of rhythm (i.e. with a fundamental larger than 1/16 second) will actually compress the range of values, since they are limited above by unity. Too much range compression would lead us again to the problem where distinctions would be too small to perceive.

We do not fully understand Stockhausen's misgivings about this "subharmonic scale of proportions", especially since his objections, based on his serial principles, to the uneven proportions and hierarchical pre-ordainment of successive durations, are hard to appreciate, some 35 years later in a time with different compositional aesthetics.

Stockhausen writes that composers tried to work around the shortcomings of such a system by such tactics as transposing the mode up and down when necessary (changing the underlying metronome speed) to reduce the range between largest and smallest units, but he feels that this violated one of the stipulations of the serial system, that the absolute tempo of the shortest duration should be fixed. This is because the proportions, his all-important unchanging "light" in which the ever-changing "objects" are to be viewed in ([Cott1973], p. 225]), would be obscured by such changes.

The serial composers who tried to work with this subharmonic series of proportion also had to resort to writing different "parts", each in its own layer of durational series, which are all then superimposed on one another. Stockhausen criticizes this writing of "parts" as being inappropriate in serial music, and criticizes polyrhythms in general too.

Stockhausen tries once again to derive a truly chromatic scale of durations (Column 2 of Table 2) this time by dividing a largest time unit again, like he did in our Column 2 of Table 1, but with a fundamental unit of 1/100 second this time, to bring this series into the sphere of pitch like the last example. This time he produces a harmonic series of durations, which again is seen to be another mode when he displays it on the musical staff as pitches, going up in pitch instead of down like the last one.

Now we come to a crucial turning point in his presentation. The notes which he composes with, in the sphere of pitch, are each composed roughly of harmonic overtone series built on fundamental frequencies just like Column 2 of Table 2. Yet these harmonic pitches can be treated as elements of a chromatic series, in spite of their internal harmonic nature. He calls this a "contradiction" between the harmonic and chromatic scales of perception. Thus there is an inner and an outer nature to the notes, which must be treated separately and not confused. His serial system has to operate on objects at some level, but those objects can then have an internal structure which may also be built up serially, or harmonically.

At the end of our previous section, we quoted H. Vaggione ([Vaggione1990]), who spoke of digital sound-objects being "open" to internal timbral composition, or "closed" under some name, made available to note-based composition. This is basically the 1990's digital object-oriented restatement of Stockhausen's key concept here. To achieve the flexibility he desires in a compositional system, he must have access to both the open and the closed representations of a musical object, in the domains Stockhausen refers to as the sphere of pitch and the sphere of rhythm, which in the 1990's presentation are, respectively, "quantum" and "fractal" in nature ([Laske1990]).

It appears that Stockhausen's discovery of the use of individual impulses to open up the micro-time structure of sound-objects, unlocking some of the puzzles that limited previous searches for musical parameters to serialize, has led to the limit, hence the breakdown ,of his former serial system of totally organized composition. He expresses the breakdown here not only in the form of this contradiction between the "harmonic scale of perception" and the "chromatic scale of perception", but more importantly in the other contradiction he mentions twice later on, between "material and method", between the actual nature of sonic objects and his cherished serial principles! And in order to continue composing, he suggests later, one must come to terms with his new concept of musical time (i.e. the second one presented in his article! - the first was the notion that pitch and rhythm are reflections of the same phenomena, but on different time-scales), in which the variability of the human performer becomes an explicit element, a resource of new life in the music that had grown sterile with the limits ot total serial control.

Now Stockhausen explains that the key to deriving a chromatic series of durations is to apply this contradiction (between the harmonic and chromatic scales of perception), discovered in the sphere of pitch, to the sphere of duration. He does so, and this would seem to be his moment of triumph.

But in reaching this goal, where he can now apply the principle of total serial organization to duration, he finds that other considerations appear, new ones resulting from performance variability and "statistical", or mass-structure, which he finds interesting, perhaps more attractive than his initial goal, now that it has been reached. And these new considerations are examined in the remainder of his article.

So his compositional system reaches new levels and matures. And as a result, he also begins to compromise and change his serial system, to retreat from the absolute principles of total quantitative organization, that so dominated his and other composers' thinking in the previous six or seven years, to a new principle of qualitative structure, which would eventually evolve so far as to allow him to claim that he still followed "serial thinking" even in his improvisational and intuitive space music of the 1960's and 1970's - refer to the quote from our section on serialism, ([Cott1973], p. 100

We now discuss how he finally obtains a true chromatic scale of durations. Columns 1 and 2 of Table 3 show the result when he takes a fundamental unit, a frequency of 1 cycle per second which he denotes by the metronome marking MM = 60, and multiplies it by the 12th root of two, the same way one multiplies a fundamental frequency to derive a 12-note equal-tempered chromatic pitch scale.

In our Column 1 of Table 3, we have followed our convention of notating durations, and in Column 2 of Table 3, we give the corresponding MM metronome markings. We use the numerical approximation 1.05946 to the irrational number which is the 12th root of 2. Each successive scale degree is obtained through multiplication by this factor, in Column 1, or through multiplication by its reciprocal, i.e. division by this factor, in Column 2 (since, as Fokker pointed out, frequency is the reciprocal of the metronome marking, subject to scaling by time-units in seconds instead of minutes).

Table 3

Column 0	Column 1	Column 2
	From p. 21	From p. 21
Chromatic number	Chromatic duration	MM markings for Column 6
	(x 12th root of 2)	
13 (A octave)	0.500 sec.	MM = 120
12 (Gsharp)	0.530 sec.	MM = 113.3
11 (G)	0.561 sec.	MM =106.9
10 (Fsharp)	0.597 sec.	MM= 100.9
9 (F)	0.630 sec.	MM = 95.2
8 (E)	0.667 sec.	MM = 89.9
7 (Dsharp)	0.707 sec.	MM = 84.9
6 (D)	0.749 sec.	MM =80.1
5 (Csharp)	0.794 sec.	MM =75.6
4 (C)	0.841 sec.	MM = 71.4
3 (B)	0.891 sec.	MM = 67.3 (67.4?)
2 (Asharp)	0.944 sec.	MM = 63.6
1 (A)	1 sec.	MM = 60

For the case of the third scale degree in Column 2 of Table 3, our calculations (60 x 1.059463) give a result of MM = 67.3 when rounded off to one significant decimal place, but Stockhausen's example listed the value MM = 67.4. All our other numbers agree with his, except for this one.

The problem with the resultant scale of durations is that most of the values have to be rounded off to approximate decimal numbers, and can't be represented well on a real-life metronome, but he is willing to put up with some imprecision.

Once he has fixed this chromatic scale of durations, he wants to apply his serial principles to it, first choosing a serial row, then fixing the register of each value, etc., but freely translating between the sphere of pitch and the sphere of duration, so he is trying to maintain an abstract level of proportions, which are instantiated on the two levels of pitch-perception (higher frequency) and duration-perception (much lower frequency).

We now consider his examples 8 - 12, on his pp. 22 - 23, summarized and clarified in our Table 4.

Table 4

Column 0	Column 1	Column 2	Column 3	Column 4	Column 5	Column 6
No. in Series (read up)	Chosen Pitch Class	Steps to Next Element	MM No.	Register Choices	Octave Trans.	MM Unit (based on Half Note)
12	G5	-6	106.9	G5	+0	Half note
11	Dsharp5	+4	84.9	Dsharp4	-1	Whole note
10	Gsharp5	-5	113.3	Gsharp4	-1	Whole note
9	F5	+3	95.2	F5	+0	Half note
8	E5	+1	89.9	E4	-1	Whole note
7	Fsharp5	-2	100.9	Fsharp2	-3	Whole X 4
6	C5	+6	71.4	C3	-2	Whole X 2
5	Asharp4	+2	63.6	Asharp3	-1	Whole note
4	B4	-1	67.4	B4	+0	1/2 note
3	D5	-3	80.1	D4	-1	Whole note

2	A4	+5	60	A3	-1	Whole note
1	Csharp5	-4	75.6	Csharp6	+1	1/4 note

The first step of his serial procedure is to choose a row-order for the series. He displays his chosen series first in the pitch domain, as note-heads on the musical staff. We list the pitches in Column 1 of Table 4. In his example, he has written them all in the octave starting with A4; that is, from his lowest note head at A4, up to B4, then C5 through his highest note at Gsharp5. We need to keep the octave register numbers straight, since we are using columns of alphanumeric symbols instead of note heads on a musical staff for our representation of his examples. We are confused as to why he does not merely work with octave-less pitch classes at this point, and apply his serial principle to the scale of possible octave registers to devise a series of octave transpositions to be applied to the pitch classes....

He has written in signed numbers indicating, for each element of his series, the number of chromatic half-steps up or down to the next element. We list these in Column 2 of Table 4. Thus from the first element C sharp to the second element A, we must descend by 4 half-steps in the negative direction, and from the second element A to the third element D, we ascend by 5 half-steps in the positive direction.

Note that when we ascend by one half-step in the positive direction, we are actually multiplying a base frequency value by the 12th root of 2 (1.05946) to get a new frequency value, and when we descend by one half-step in the negative direction, we are actually dividing the base frequency by the 12th root of 2. But in the sphere of pitch, we have a convenient shorthand, in the alphabetical note names, for indicating this underlying mathematical procedure.

Next he has indicated (see our Column 3 of Table 4) the corresponding MM metronome tempi, which he previously assigned via logarithmic calculations to each scale degree in his chromatic scale of durations, in the sphere of duration, for each element of the series. Although the correspondence is not spelled out explicitly, we deduce that he is arbitrarily using the alphabetical notation of the pitch class A (denoted on his musical staff by a note head at A4) for the fundamental pitch in his chromatic pitch scale.

The evidence we rely on for this deduction is that the note A is shown to correspond to the tempo MM = 60. And we recall from Column 2 of our previous Table 3, where we listed the tempi he assigned to his chromatic scale of durations that is now being taken as the basis for this choice of duration/tempo elements in series order, that the fundamental duration was assigned MM = 60 there. Therefore, since the note A apparently corresponds to MM = 60, and since MM = 60 was specified as the fundamental duration, we reason that A must be the fundamental pitch in his pitch scale.

The "steps to next element" listed in our column 2 of Table 4 now apply, in the sphere of duration as well as in the sphere of pitch. They still correspond to multiplication of a base value by the 12th root of 2, but since we have no alphabetical note names as a shorthand for this procedure, we must write down the exact metronome tempi instead, (rounded off to one significant decimal place) in Column 3 of Table 4. The first element of the series, in the sphere of duration, is the tempo MM = 75.6.

We can refer back to Columns 0 and 2 of our Table 3, to verify that his original construction of a chromatic scale of durations assigned the tempo 75.6 to the 5th degree of the scale, which has the alphabetical note name Csharp if one starts from degree 1 as the note name A. And we actually do use Columns 0 and 2 of our Table 3 in this fashion, along with Column 1 of Table 4, to produce the entire Column 3 of Table 4, finding the tempo which corresponds to the scale degree which in turn corresponds to the alphabetical note name of the next element in Stockhausen's chosen series.

We use Column 2 of Table 4 to verify that the tempo numbers are correct -- we carry out the actual multiplication of the previous tempo value in the series by the 12th root of 2, raised to the power given by the next highest element of Column 2 of Table 4(the number of steps to the next element), which then yields the next highest element of Column 3 of Table 4.

The next step (see Columns 4 and 5 of Table 4) is to place the pitches of the series in octave registers, and to carry out the analogous operation in the sphere of durations. This is a series of octave transpositions, one for each element of the series. The register choices in the sphere of pitch are given in our Column 4 of Table 4 as alphanumeric note names, and the signed magnitude of the octave transpositions from the original portrayal of the pitch series is given in Column 5 of Table 4.

We wonder how the sequence of octave transpositions (Column 5 of Table 4) was chosen; why did he not discuss this in the context of his serial method?

We would expect, for the next step of this procedure, to apply the octave transpositions of Column 5, element-by-element, to the series of metronomic tempi in Column 3. We expect to put the results in Column 6 of Table 4. Stockhausen does something unexpected here though.

Octave transposition corresponds to multiplying by 2 for each octave up, or dividing by 2 for each octave down. Thus, for the first series element MM = 75.6 to be transposed +1 octave, we would expect a new tempo of MM = 151.2 to be the result. But instead, Stockhausen carries out the octave transpositions by using a different note-head to denote the fundamental durational unit of each series element in its transposed form, without changing the tempo number itself. He starts with a basic unit of one half note as the original assignment.

Thus for the first series element MM = 75.6 transposed +1 octave, he keeps the MM tempo of 75.6, but assigns the note value of one quarter note to it, since a quarter note is twice as short in duration as the original half note. For the second series element of MM = 60 transposed -1 octave, he writes MM whole note = 60. And so on, for all the elements of the series.

Column 6 of Table 4 lists the note head values. Each one corresponds to the octave transposition register in Column 5 of Table 4 beside it, with the origin, corresponding to +0 transposition, denoted as a half note.

Table 5

Column 0	Column 1	Column 2	Column 3	Column 4	Column 5
No. in Series (read up)	Rounded Metrical Series	2nd Rounded Metrical Marks	Stockhausen "harmonic proportions"	Fokker corrected proportions	Fundamental durations
12	1/2@Q= 107	H=103	(?? not given)	(8:11)	5/9 sec.
11	2/2@H= 85	W=87.3	4:10	7:5	1-4/11 sec.
10	2/2@H= 113	W=110.4	12:9	18:7	1-1/29 ?sec.
9	1/2@H= 95	H=97.7	5:3	3:4	3/5 sec.
8	2/2@H= 90	W=89.6	6:13	7:12	1-1/3 sec.
7	2/2@H= 101	4xW.=102.4	2:7	15:7	4-11/16 sec.
6	4/2@H= 72? (71)	2xW.=70.3	11:8	25:7	3-3/8 ? sec.
5	2/2@H= 64	W=63.3	9:5	7:10	1-7/8 sec.
4	1/2@H= 67	H=63.5	13:6	4:7	7/8 sec.
3	2/2@H= 80	W=80	7:12	(7?) 9:15	1-1/2 sec.
2	2/2@H= 60	W=60	3:4	4:3	2 sec.
1	1/4@Q= 76	Q=75	10:2	5:1	2/5 sec.

Next comes a transformation which we do not understand, which results in Column 1 of Table 5. Stockhausen's remark ([p. 22]) is "If this were barred normally, the result would be the following metrical series..." and then he gives a set of new specifications for each series element. Each element has a note head unit value and a metronomical tempo, but it also has an indication of the measure.

Thus the first series element is a measure of 1/4, at MM quarter note = 76. Every other series element after the first one has a measure with 2 in the denominator instead of the 4 that this first measure has in its denominator, and we don't understand why the denominator is varied only for this first measure.

Perhaps because it is the only one which involved an octave transposition of +1, in contrast to the rest of the series elements which all have either zero transposition or else have negative octave transpositions, in magnitudes ranging from -1 to -3. Perhaps there is an unstated principle here that the denominator of the measure indicator should only change when the underlying unit has to get smaller than the fundamental half note; the other series elements just involve larger multiples of the fundamental half note so that the constant unit of half note can be carried through them all, just by changing the numerators of each measure indicator to match the magnitude of the octave transposition.

But this cannot explain why the quadruple-whole-note series element (#7) and the double-whole-note series element (#6) get a measure of 2/2 time, which is the same as the whole-note gets! It seems that information is being discarded here and we don't understand the principle involved. Only the half-notes get a new measure numerator, making them a single 1/2 time measure of MM half note = 67 for series element #4, MM = 95 for element #9, and MM = 107 for element #12.

And the metronome tempi have been rounded off to the nearest whole number, except for the case of element #6, original MM = 71.4, new value MM = 72 (which should be 71 to be consistent with the rest of the series, which has followed the standard rule of rounding up for a decimal value greater than .5 and rounding down for a decimal value less than .5).

Stockhausen mentions a simplification which can be made in series elements #3 and #11, because they follow in a simple harmonic ratio from the preceding series element. Thus #3 which is notated as a 2/2 measure of half note = 80 follows a measure of half note = 60, and this forms a ratio of 80:60 = 4:3, so he rewrites series element #3 as a measure of 3/4 time at the same tempo as the previous measure (i.e. half note = 60).

Similarly, he shows series element measure #10 is a measure of 2/2 time at half note = 113, and measure #11 is a measure of 2/2 time at half note = 85, and somehow he must be rounding off measure #11's tempo to MM = 84.75 which puts the two elements in a ratio of 113:84.75 = 3:2, so he rewrites series element #10 as a measure of 3/4 time at its previous MM = 85, followed by measure element #11 as a measure of 2/2 time at this same tempo. He seems to be rounding up and down at will to make things approximately fit a tempo scheme that will be easier to count and conduct. (we have not made these two simplifications in our Table 5, however).

Now he addresses our question concerning the octave register placements selected to transform Column 1 of Table 4 into Column 4 of Table 4 in the sphere of pitch, and Column 3 of Table 4 in the sphere of duration into Column 1 of Table 5. We asked whether the choice of octave registers was made arbitrarily, and why it was not treated according to his serial principles.

He mentions that "One is misled into doing things in this order" ([p. 23]) because the chromatic series with its unit interval of the 12th root of 2 between successive scale elements is assumed. And then he says something which shows a significant breakdown of his previously strict serial principles - he says that it is not as interesting, when listening to series, to observe that all the chromatic steps should appear, as it is to observe which proportions are chosen between the elements of the series; that is, to see how the series elements are composed in relation to one another (even if some of them are left out?) He seems to be violating a cardinal principle of his previous serial system, by allowing the possibility of using a "mode", even though he spoke out against modes and their inappropriateness in the serial method, earlier in this same article.

Following this drastic announcement, he now rewrites the series in terms of the all-important ratios, or intervals, between successive elements. Thus, instead of deriving the "steps to next element" which we wrote in Column 2 of Table 4 previously, from the elements themselves, he derives the elements themselves from the ratios. He first specifies a series of ratios, and a given first element of the derived pitch/duration value series. Then all the elements of the pitch and duration series follow from these generators

And he writes pure small-number ratios, admitting that the resultant actual elements will deviate from the chromatic equal-tempered values. This then violates the second of the cardinal principles of his previous serial system, because the elements of the derived pitch and durations scales which result do not completely cover the spectrum in equal-valued steps!

It seems that he has had to remake his serial system in order for it to survive the contradictions he has pointed out in his article - the contradiction between the harmonic and chromatic "scales of perception" on the one hand, which is leading him to accept deviations from his equal-stepped chromatic scales, including the possible omitting of certain elements, resulting in the "modes" which he spoke out against, and the contradiction between the "material and the method" on the other hand, (his serial system and the human interpreters) which is leading him to simplify, through arbitrary and sometimes inaccurate rounding-off, the tempo numbers his system is generating, presumably in the interest of easier performance by human musicians and conductors.

He writes out a series of proportions which, he indicates, approximately express the ratios of the successive elements of the fundamental durations/pitches in his previously selected element-series. And he lists a new set of metronome markings, which we are asked to compare with the previous set (listed as the right side of the @-signs in our Column 1 of Table 5, i.e. disregarding the measure time signatures to the left of the @-signs).

We list these new metronome markings as Column 2 of Table 5, and we list these "harmonic proportions" ([p. 23]) in our Column 3 of Table 5. These metronome markings presumably arise from multiplying a fundamental tempo by the successive ratios of this new harmonic proportion series, but we are not quite sure of the details, since there used to be a fundamental tempo of MM half note = 60 in the 2nd element of the series, but it has now been transformed into a whole note = 60 through some means we do not understand.

At this point, we turn to physicist Adriaan Fokker, who has been trying to follow Stockhausen's complex procedure in an attempt to help explain it more simply, because we do not understand this next step at all ourselves!.

And Fokker indicates that Stockhausen's series of "harmonic proportions" contains some glaring errors which seem to be deliberate distortions. We list Fokker's corrected proportions in Column 4 of Table 5, alongside Stockhausen's proportions.

Fokker questions why Stockhausen has chosen more complex ratios, with higher integers in them, and has even chosen inaccurate ones, like the 7:12 for a major sixth interval which should be 3:5 (Fokker is "startled" by this "high-handed procedure", [Fokker1962] p. 72). Unfortunately, the text of Fokker's article shows 7:15 as his correction for Stockhausen's 7:12 in the ratio of the 8th scale element to its upper neighbor, so we are confused; perhaps it is a typographical error and should be 9:15 = 3:5, and we have written it so in our Column 4 of Table 5.

Fokker lists other problems with Stockhausen's interval series: Asharp through C to Fsharp is written as 5/9 x 11/8 = 99/40, but Fokker says it should be 100/40 = 5/2, giving a much simpler ratio. C through Fsharp to E should be 2/5 = 22/55 but Stockhausen has written it as 11/8 x 2/7 = 22/56. E to Gsharp should be 4:5, but Stockhausen has written 6/13 x 5/3 = 10/13 = 20/26 instead of 20/25 which reduces to 4/5. Stockhausen correctly writes 5/3 for F to Aflat, but also uses the same ratio for F to Gsharp, which is wrong (the correct ratio is 12/7). Stockhausen has written 7/12 for the major sixth from D to B, and is hence off by a factor of 35/36. And the interval C to Fsharp, which Stockhausen wrote as 11/8, should be 10/7.

Fokker asks, after pointing out all these discrepancies, "It is an amazing puzzle. Why was the author unaware of these discrepancies?" (op.cit.) Stockhausen has made errors of an entire semitone (25/26 and 77/80) in magnitude, which are quite audible in the sphere of pitch intervals.

Finally, Fokker notes that Stockhausen left out one ratio. Substituting a value of 11/8 for the empty spot (at the 12th scale degree in our Column 3 of Table 5), and thereby returning from G to Csharp for the next octave of the series, as one would naturally expect, Fokker notices that Stockhausen would have written out a collection of fractions where all the numbers from 2 through 13 have appeared, both somewhere in the numerators and somewhere in the denominators.

"The completeness would be lost if any of the discrepancies shown were to be amended. That is true. But there is no reason for that. What is the use of such a frivolous play with, or of such regard for, numbers? Is there any music in it? If any of us, physicists or other scientists, were to offer this sort of argument, we should certainly be reminded at once that numbers do not make music. The author [Stockhausen], however, is quite an honourable and serious musician. I therefore feel justified in asking: what is the musical sense of such a dance with numbers, which so obviously falsify actual facts?" (op. cit.)

We have one more column remaining in our Table 5 -- in Column 5, we list the fundamental durations that Stockhausen finally lists, in seconds, for the elements of the series, after all the rounding off has been completed to his satisfaction.

The first element is given as 2/5 seconds duration. Looking back at our previous tables, this element comes from an original pitch-series note Csharp6, and a MM marking of a 1/4 time measure at quarter note = 75.6 (subsequently rounded off first to 76 for Column 1 of Table 5, then rounded off to 75, for Column 2 of Table 5. We should be able to find some fundamental somewhere, probably related to either half note = 60 or whole note = 60, which is in a 5/2 ratio with some aspect of this element #1, presumably with the new rounded metrical mark quarter note = 75. We do note that 75 x (2/5) = 30, which is 1/2 of 60, so there must be some relation among the half note, quarter note, and whole note units which makes this come out right.

Since the 2nd series element, which should still correspond to the original fundamental (it was an A3 in the sphere of pitch, and MM half note = 60 in duration, before the most confusing transformations), is listed as having a duration now of 2 seconds, this would suggest the factor of 2 needed to match 75 x (2/5 seconds) = 30 and somehow relate it to the original MM = 60, but we are at a loss to explain how this exactly works out. It doesn't seem to be that essential to Stockhausen's purpose anyway.

All of this lengthy buildup, from the derivation of a chromatic scale of durations through the establishment of a corresponding series, rounded off somehow, and related to an intervening series of mysterious small-number ratio proportions, has been merely a prelude to the next subject. Now Stockhausen introduces Groups of fundamental durations, where the numerators of the proportional ratios indicate a first group-half and its division into sub-parts, and the denominators of the proportional ratios indicate a second group-half and its division into sub-parts.

Fokker suggests a new terminology to make this idea clearer. He has been denoting time-intervals as "whiles" instead of Stockhausen's misnomer "phases"; more specifically, he calls time-intervals in the sphere of duration "macrowhiles", and calls time-intervals in the sphere of pitch "microwhiles". Then this lengthy procedure of establishing a series whose elements correspond on the one hand to pitches and on the other hand to durations is a process of establishing proportional relations between macrowhiles and microwhiles:

"[Stockhausen] does not carry the idea of placing macrowhiles proportional to microwhiles to its conclusion. He inverts the idea. He takes a number of macrowhiles together in a group. For the sake of definite clarity I propose to call such a group a super-while. I want a special word, because it is not easy to explain the intricate procedure of the author.

"He places two equal super-whiles in succession. Each is divided into a number of macro-whiles. The two numbers should be proportional to the frequencies to the microwhiles concerned in the interval which has to be represented. However, he never uses the word frequency...." ([Fokker1962], p. 73)

Stockhausen is using, as input for high-level construction procedures, the numerator and denominator of each ratio in the series of "harmonic proportions" that he derived from the elements of his pitch/duration built on a permutation of his long-sought chromatic scale of durations. Recalling that Fokker has indicated the erroneous nature of many of these ratios, at least if they are supposed to truly represent the underlying series of duration/pitch elements, we see that Stockhausen is basically using numbers which he has constructed arbitrarily for their own sake. For example, Stockhausen uses 7/12 instead of the 3/5 which Fokker points out as the true ratio representing a major sixth interval; so Stockhausen's "super-while" equal-duration groups of "macrowhiles", which are divided, the first half into 7 equal parts and the second half into 12 equal parts, cannot be taken as a representation of the original frequency ratio in the sphere of duration.

It is evident that Stockhausen has shifted paradigms on us, leaving behind his original goal of establishing correspondence between pitch and duration for the purpose of total serial control, and instead pursuing a new goal in this new context of groups. This new goal is the composition of a work like "Gruppen" where three separate orchestras play different metres and rhythms (Stockhausen's "formant-spectra") in different spatial locations, with variability and uncertainty as an explicit factor in the composition.

The prescribed series of intervals is 10:2, 3:4, 7:12, 13:6, etc. Stockhausen has two equal super-whiles, which he calls groups. The first super-while (obtained from the first element of the original series of durations, i.e. the one involving quarter note = 76 tempo, now mysteriously changed once again into half note = 76) is divided into ten macrowhiles, namely ten quarter notes; the second super-while (from the original fundamental duration, half note = 60), which is the second half of this group-pair, is divided into two macrowhiles, namely two whole notes. These are super-whiles to which, as a pair, Fokker assigns the number I.

For the next proportion 3:4, one needs a super-while with three macro-whiles. The last of the now extant superwhiles I contains only 2 macrowhiles (the two whole notes), so a third macrowhile is added, extending a super-while I (the 2nd one) to a super-while II, containing 3 macrowhiles. Then an equal super-whileII follows, divided into 4 equal macrowhiles. For the next proportion 7:12, we have to extend this last super-while II by adding 3 more equal macro-whiles to give a new superwhile III with 7 equal macro-whiles. An equal super-while III follows, divided into 12 equal macro-whiles. This procedure is continued, adding a new super-while after extending the last one to get the right number of divisions for the numerator of the next proportion. So the interval 10/2 is served by super-whiles I, the 2nd proportion 3/4 is served by super-whiles II, ..., the proportion 11:8 is served by super-whiles VI, 2/7 is served by super-whiles VII, etc...

The posterior super-while VI contains 8 macro-whiles. The anterior super-while VII must contain no more than 2 macro-whiles. After these the posterior super-while VII enters. The anterior part of the first super-while VII overlaps with the posterior part of the second super-while VI. More overlappings occur elsewhere in the serial structure.

Stockhausen then says

"... in this way different numbers of equal duration (macrowhiles) are united in groups (super-whiles): these are equal in length from one group to the next (the first ten macro-whiles are equal in length to the next 2 macro-whiles)....Every group (super-while), however, with the exception of the first and the last, is ambiguous. It is a second member of a first interval (10:2) and a first member of a next interval (3/4).... From this ambiguity the result is either rests or temporal superpositions" ([p. 24]).

But Fokker says this is wrong, there is no ambiguity. The previous super-while is not actually a first member of the next interval, because of the rests that must be added. The new super-while, which consists of the old super-while plus new rests, is a different entity from the old one, so there is no ambiguity at all.

So in the first super-while II the so called 'group' contains two macro-whiles of the second super-while I, then also contains 1 rest, in order to make a complete super-while II of 3 macro-whiles. There are two "groups", with some constituent macro-whiles serving as members of both. The "temporal superposition" that Stockhausen mentions, according to Fokker, relates to the super-while VI (for the proportion 11/8) being longer (8 is larger than 2) than the superwhile VII (for the proportion 2/7) and this super-while is again longer (7 larger than 6, in the next super-while VIII for the proportion 6/13).

Stockhausen's diagram shows that sometimes, four super-whiles overlap. We are in agreement with Fokker; there is no ambiguity, and there is no "temporal superposition", there are merely multiple hierarchical levels, with shared elements playing different roles in the different entities at higher levels. We recall, however, that one of Stockhausen's previously expressed serial principles (if it isn't one he has abandoned along with the need for comprehensive equally-spaced intervals and for exact precise values with no rounding off, that is) is the inappropriateness of hierarchies in serial music. Perhaps Stockhausen is reluctant to look at this situation in the most natural way, in terms of multiply overlapping hierarchies, for this lingering ideological reason.

"Here again, if some scientist happened to hatch a temporal construction like that, intrigued by what looks so interesting on paper, everybody would ignore it. The author, however, is an honourable leading composer. We must presume that there are other composers who are working with such things and who can find use for them in their music." ([Fokker1962], p. 75)

"...These observations have been critical but I must emphasise that I want to support these endeavours at innovations in a constructive mood. I am not too old to understand that there are great problems which have to be tackled in the face of new possibilities. If someone attempts to present a scientific account of his aims and methods, we have to consider his endeavour with sympathy and with a realisation of its promise. But he ought not to invest scientific terms with other meanings....

"Pseudo-science is no better than pseudo-music. The explanations should be given in the simplest manner in the most familiar words. Where I have been denouncing failures, these denouncements belong to the feedbacks (in the sense of cybernetics) which have to be activated whenever a great task is attempted." ([ibid.] p. 79)

And those are Fokker's last words on the subject. We end this example, and this section of the paper, with one final thoughtful quote from Gottfried Michael Koenig's article which concluded the literary dialogue engendered by Stockhausen's paper.

"When studying theoretical articles, which the composers themselves must provide today, one must clearly distinguish between musical facts and resources of presentation frequently borrowed from mathematics. A widely-spread superstition is that composers of serial music are really mathematicians or at least arithmeticians; in the case of electronic music that they are really technicians or sound-engineers. Unfortunately the people who are taken in by such rumours do not bother to convince themselves of the actual state of affairs by glancing at the scores.... Anybody in need of a plumber is also happy if the latter can also get a bent lock open. But woe betide the composer who knows how to work with logarithm tables, or who puts his nose in a book in order to find about the physiological processes of hearing. He who has contact with music has his own ideas, however they may be, about it; it is not always his fault if they are wrong. Only intellectual theft is spoken of; but the removal of mistaknness and untruth is at least as strictly punished. The confusion of music with non-musical assistance keeps on penetrating the music itself. Since serial music has been being composed, the opposition has not died out; now that some composers are beginning to transcend serialism too, the lie-a-beds and reactionaries are getting up and wanting to preserve serialism at least. Once one is used to opposing, one gets angry when the resistance disappears. There are reasons for assuming that it is evaporating even in composing. Especially as serialism -- as a coming-to-itself of all rationalisation in music -- favours the interception of all laterals in systematically placed nets. A sort of auto-motion is imputed to the musical material, the composer passing on the pressure from above....."

"...Music could be said to be the practical superstructure of theory. But this would cede to the latter a priority which it does not possess. By penetrating the form, what is heard inwardly assumes something of its constraint. It easily degenerates to an agreeable arrangement, to applied art." ([Koenig1962], p. 98)

A Comparison of Henry Cowell's Rhythmic Concept With Stockhausen's

In his treatise ([Cowell1930]) written in 1919 (but not published until 1930), Henry Cowell discusses the overtone series at length. He applies the overtone series to set up scales of metre, duration, and tempo, which are, in his treatment, the three elements that make up rhythm.

"It is difficult to find musical means to which overtones do not apply, or may not be applied, as they may be used to measure all relationships of steady pitch, no matter how subtle are the degrees of pitch chosen; ***and all rhythmical relationships can be derived from overtones, as will be shown****. .." ([p. 20])*

Cowell mentions "undertones", descending sequences of partials, what Stockhausen refers to as "subharmonic series of proportions". To Cowell, they arise naturally from properties of acoustics, and they are related to overtones, or ascending sequences of partials, in ways that parallel the relationship of "minor" intervals to "major" intervals. He is on a quest for "new musical resources", as is Stockhausen in his search for ways to parameterize and unify the microstructure and macrostructure of sound, but Cowell does not share Stockhausen's view that "modes", like this series of undertones, are inappropriate in his music.

Cowell sets up a scale based on tone-qualities (evidently referring specifically to the aspect of timbre dependent on the presence and relative amplitude of different harmonic overtones in a continuous tone). This characterization looks very much like the serial treatment of such a timbral parameter might look, except for the prominence of harmonic, instead of chromatic, qualities as his structural organizing principle:

"It will be seen that the problem of forming a related series of tone-qualities is the same as in other branches. A scale can be made by placing in the same group the tone-qualities in which overtones from the same proportion of the series are most prominent; thus a quality in which the first overtone is most evident might be number one in the scale; a quality in which the second overtone is most plainly heard might be number two, etc. A quality strongly posessing both the first and the second overtones would be a bridge from number one to number two in the scale, and might be classified as a `harmonic' quality, as it would be produced through a combination of sounds....

"If tone-qualities were arranged in order, and a notation found for them, it would be of assistance to composer and performer alike.... Tone-quality thus becomes one of the elements in the composition itself and ceases to be only a matter of performance.....Progress in the field of new or graduated tone-qualities in composition has been greatly hindered by lack of notation, as it has been justly felt that if music demanding new tonal values were set down in present notation, the desired effect would be likely to be entirely lost in the performance." ([p. 34])

Cowell is more systematic than Stockhausen in his definitions of terms that he uses. He defines duration, metre, and tempo as sub-divisions of a general "rhythm" category, and proceeds to develop the relationship of rhythm to sound-vibrations -- in Stockhausen's terms, the "sphere of duration" is considered in terms taken from the "sphere of pitch", over 35 years before Stockhausen's article.

"... one general idea will be dealt with -- namely, that of the relationship of rhythm to sound-vibration, and through this relationship and the application of overtone ratios, the building of ordered systems of harmony and counterpoint in rhythm, which have an exact relationship to tonal harmony and counterpoint.... In the discussion of musical rhythm in its elements, time, metre, and tempo, it will be seen that the problems here considered are not only related to, but based on, principles that are already familiar in the field of harmony and counterpoint -- that is, in the relation of tones to one another......" ([pp. 45 - 46])

Cowell constructs a chart showing that in one time interval, if a fundamental tone C = 16 cycles per second vibrates 16 times, the octave vibrates 32 times, the fifth 48 times, etc. Calling partial #1,2,4 by the note name "C", partial #3 "G", and partial #5 "E", he notes that the collection G, C, E (partial #'s 3,4,5) vibrate at 48, 64, 80 times in this interval, i.e. G vibrates 3 times, while C vibrates 4 times, and E vibrates 5 times, in one sub-unit of time.

This is simply stating the relationships of the frequencies of the partials to the frequency of the first partial, or fundamental. The number of vibrations in one fundamental cycle made by a given partial is just the number, in the overtone series, of that partial! i.e. partial #5, E, vibrates 5 times in the interval.

Then he extends this relationship to the sphere of rhythm as follows:

"If we anticipate for a moment what is to be said in regard to musical rhythm, and desire to represent graphically the result of playing simultaneously three parts which would equally divide a whole note into three, four, and five parts respectively, we should have a diagram of exactly similar form. The smaller units are the fractional notes that perfectly fill the measure. And the principle of beats that coincide, then separate, then coincide again, can be seen to be identical." ([p. 45])

Now he covers the three aspects of rhythm individually - time, metre, and tempo. He mentions that the fundamental unit of measuring musical time or duration is the whole note, and that it can be divided up by half, quarter, eight, sixteenth notes, etc., and also by combining these shorter units into so-called "figures".

Stockhausen, on the other hand, points out that this division of a largest fundamental durational unit into smaller and smaller partials is just one way of treating durations - Stockhausen also explores the multiplication of a smallest unit, yielding larger and larger partials, for example. We will see that Cowell also sets up such a scale when he treats metrical meter with the overtone series.

Cowell discusses the problem of notating the division of a whole note into three equal parts, into what we call a "triplet". We recall that Stockhausen began his construction of durational scales with similar questions about the inadequacy of traditional notation for duration:

"...there is no way of doing so except by the clumsy expedient of writing the figure 3 over three successive half-notes filling a measure. In other words the notes as written down have a certain time-value impossible under the circumstances, and the discrepancy is reconciled by explaining that in reality notes of a different time-value are intended. Were the use of such notes of rare occurrence, this method might be justifiable; since, however, these notes and others having a similar discrepancy in time are very often used, should not an independent method of notation be found for them?" ([p. 50])

Cowell also makes the reverse connection, as Stockhausen does, namely that speeding up a periodic rhythmic figure by a sufficient amount will result in the perception of a continuous tone. He gives an example of taking two simultaneous melodies, one played twice as fast as the other, with the common underlying pulse indicated by the tapping of a stick,

"If now the taps were to be increased greatly in rapidity without changing the relative speed, it will be seen that when the taps for the first melody reach sixteen to the second, those for the second melody will be thirty-two to the second. In other words, the vibrations from the taps of one melody will give the musical tone C, while those of the other will give the tone C one octave higher. Time has been translated, as it were, into musical tone. Or, as has been shown above, a parallel can be drawn between the ratio of rhythmical beats and the ratio of musical tones by virtue of the common mathematical basis of both musical time and musical tone. The two times, in this view, might be said to be `in harmony', the simplest possible."

Electronic studio music had not been invented yet, although the Theremin was widely known before the publication of Cowell's book (Leon Theremin and Henry Cowell were acquaintances, as we shall see). But Cowell still managed to gain the insight about rhythmic impulses which can merge into an audio stream at fast enough rates, from observations of the steam-driven siren:

"There is a well-known acoustical instrument [Joscelyn Godwin's note points out that this is a siren] which produces a sound broken by silences. When the silences between the sound occur not too rapidly, the result is a rhythm. When the breaks between the sound are speeded, however, they produce a new pitch in themselves, which is regulated by the rapidity of the successive silences between the sounds."([p. 50])

Cowell has discovered harmonically-related layers of polyrhythm:

"Referring back to our chart, we find that the familiar interval of a fifth represents a vibration ratio of 2:3. Translating this into time, we might have a measure of three equal notes set over another in two. A slight complication is now added. Corresponding to the tone interval of a major third would be a time-ratio of five against four notes; the minor third would be represented by a ratio of six against five notes, and so on. If we were to combine melodies in two (or four) beats, three beats, and five beats to the measure, we should then have three parallel time-systems corresponding to the vibration speeds of a simple consonant harmony..... The conductor of such a trio, by giving one beat to a measure, could lead all the voices together; for the measure, no matter what time divisions it included, would begin and end at the same instant." ([p. 51])

He mentions more complicated variations, which would include units of the time-scheme that shift from one voice to another, and that the complete rhythmic harmony could shift at will, like a succession of different chords (the collection of interval-relationships) like in tonal harmony. (he has already discovered the "metric modulation" principle) Still further variations on polyrhythms would include sub-dividing the overall measure -- if a measure with three beats in it were sub-divided into halves, each half would take one and one-half beats. But this could be reconciled by going to a smaller sub-unit, i.e. one beat is now 2/6, so one and one-half is 3/6, in a matter which is "another application of the principle of the dotted note".

If eleven notes were to the measure and a "lower octave" was desired, that would make five and one-half beats to the measure, but this would be written using tied eleventh-notes, i.e. each of the five would be 2 11th's long, and the one-half would be 1-11th long.

"These finer rhythmical distinctions [i.e. 11th-notes, etc.] open up a new field for investigation. Not only do nearly all Oriental and primitive peoples use such shades of rhythm, but also our own virtuosi, who, instead of playing the notes just as written, often add subtle deviations of their own."([p. 55])

Cowell has also discovered the quantitative time variability of the human performer. The experiment he mentions here concerns multiple performers interpreting one constant passage of music, while Stockhausen proposes a different experiment involving the same performer interpreting differently-notated versions of the same passage, since presumably Stockhausen was already well aware of the variations that exist among different musicians:

"Professor Hornbusel, of Berlin [a note by Joscelyn Godwin suggests that this is a mis-spelling of Hornbostel, who apparently Cowell was expecting to study with in 1931, shortly after publication of the book], has made the

experiment of recording the time-values of a passage, as actually played by a capable musician. He found that the lengths of notes as played were quite irregular; for example, the first of the first two eight-notes was almost twice as short as the second, while the quarter-note following was not twice as long as either of the eighth-notes."[p. 55 - Cowell's example #8 shows four 2/4 measures, with a pickup bar of 2 eighth notes, a bar of one quarter and 2 eights, another quarter and 2 eights, and a final ending of 2 eighths.]

We recall the disagreement among Stockhausen, Backus, and H. Davies over the difficulty of performing certain fragments of very precise, fast sub-divided time units, in which Backus cast aspersions on the calibre of Stockhausen's musicians. Here is Cowell's suggestion that performers learn cross-rhythms by simply practicing them a lot. Stockhausen's situation was even more difficult, because he was not referring to a steady stream of notes, which are easier to understand and practice systematically, than his fragmentary figures, which will presumably be different in each instance.

"An argument against the development of more diversified rhythms might be their difficulty of performance. It is true that the average performer finds cross-rhythms hard to play accurately; but how much time does the average performer spend in practising them? Cross-rhythms are difficult and must be familiar before proficiency can be obtained in performing them; but if even a few minutes a day are seriously devoted to mastering them, surprising results are obtained. Surely they are as well worth learning as the scales, which students sometimes practise hours a day for years. By experiment we have observed that such rhythms as five against six against eight or nine, and other combinations of three rhythms together, can be quite accurately performed by the devotion of about fifteen minutes a day for about six months. Some of the rhythms developed through the present acoustical investigation could not be played by any living performer; but these highly engrossing rhythmical complexities could easily be cut on a player-piano roll......" ([p.64])

Now we examine Cowell's call for a new rhythmical music instrument (eventually built by Theremin):

"It is highly probably that an instrument could be devised which would mechanically produce a rhythmic ratio, but which would be controlled by hand and would therefore not be over-mechanical. For example, suppose we could have a keyboard on which when C was struck; a rhythm of eight would be sounded; when D was struck, a rhythm of nine; when E was struck, a rhythm of ten. By playing the keys with the fingers, the human element of personal expression might be retained if desired. It is heartily proposed tht such an instrument to play the scale of time-values given at the end of this chapter be constructed. On such a keyboard one might make many variations, such as playing a rhythmic chord as an arpeggio, which would result in starting the rhythmical units canonically." ([p. 64])

Strictly speaking, this instrument produces different tempi on each key, in synchronized equal-length polyrhythmic measures. Presumably notes in the given tempo would continue to sound repeatedly as long as one's finger held down the key for that tempo. The entire instrument would have to be tuned to a fundamental unit tempo, and all the keys would be fixed ratios measured from the fundamental.

Note that the scale Cowell proposes (rhythms of eight to a bar, of nine, ten, etc. and presumably he is just glossing over the accidentals in between C, D, and E!) is the same as the chromatic one that Stockhausen derived from division of a largest unit duration.

In our previous section, we listed this scale as Column 2 of Table 1, and we showed that it was equivalent to multiplying the largest unit by the reciprocal of the chromatic scale degree. Assuming that Cowell really means to set out keys in numerical order, so that key #1 plays 1 beat in a period, key #2 plays 2 beats in the same period, etc., we found that if the overall period had a duration of 1 second, that scale degree #n would have a duration of 1/n seconds; more generally, with a fundamental largest duration of M, the duration of scale degree N would be N/M.

Stockhausen, on the other hand, calls for two new musical instruments to be built. The first is a duration keyboard. Only one tone would be sounded for a single strike of a key. Instead of repeated notes at a given tempo, the single tone would sound for the given duration assigned to that key. The pitch of the note would vary according to how much pressure was brought to bear on the key.

Nowadays one could design instruments combining features of both Cowell's tempo instrument and Stockhausen's duration instrument. A single strike of a key could produce variable results according to the configuration. At one extreme setting, a keystroke could initiate an event of fixed duration as in Stockhausen's design. Variations could be available in which this single event could be subdivided according to various considerations of tempo, polyrythms, or additive rhythms (groups of events could be triggered according to various group-formation criteria). Or the event could be variable length, continuing to the release of the initiating key. A fixed tempo could be generated, as in Cowell's instrument, or other variations could be controlled by other variables such as pressure, location, and alternate actions.

With today's flexible sound modules and controllers such as Buchla's Thunder ([Buchla1990]), such instrumental setups are now possible to design and save as preset configurations, enabling the same basic hardware to support multiple instrument philosophies and layouts.

Stockhausen's call for a second instrument, which would be capable of continuously variable pitch and timbre, and continuously variable frequency bandwidth between white noise and definite pitch, is a little more tricky, but an approximation could still be set up on a Buchla Thunder with the right kind of software running on a computer that is listening to the MIDI output from the Thunder controller. Variable parameters of synthesis algorithms could be made available for continuous control with finger pressure or location on the various Thunder keys, if only the synthesis system was general-purpose enough to support such uses.

In Cowell's book, after his call for the tempo instrument, he considers metre, which he takes as "the result of rhythmically regular accent". He uses one unit, the quarter note, for reference, and considers different metres like "3/4 time", "4/4 time", "5/4 time" i.e. where the overall length of the measure is additive based on the number of units contained within (unlike the previous investigation of time where the overall length was constant and the ratio of the sub-divisions to the whole were what varied, i.e. half-notes, half-triplets, quarter notes, quarter triplets, eights, etc.). He also uses the 2/4 measure as a basis, since one could take his previous tone of C = 16 cps, transpose it down 3 octaves, and obtain 2 cps, or 2/4 metre where a measure takes up one second of duration...

In this system of metres, his overtone series gives the chart (from his [p. 68])

```
Serial          Tone       Intervals         Metre on 2/4 Base Number (Read up)
6               G          Minor third       12/4 (6/4,3/4,6/8) 5             E
Major third       10/4 (10/8, 5/4) 4              C          Fourth
8/4 (4/4, 2/4) 3               G          Fifth             6/4 (6/8, 3/4) 2
C          Octave            4/4 (4/8, 2/2) 1              C
Fundamental       2/4
```

Joscelyn Godwin's note, p. 154, points out that "whereas the entities of rhythmic organization on the level of ‘rhythm’ become smaller in proportion to the upward movement of the harmonic series, those of `metre' become progressively greater. The unity of the system breaks down at this point." For example, one would not be able to superimpose several partials within the period of one fundamental unit, because higher partials actually cover longer timespans than lower partials do. The duration of the fundamental metrical unit in this system is actually the shortest duration; the first harmonic covers twice as many beats, hence twice as much time, as the fundamental.

The bracketed metrical equivalents (i.e. 6/4, 3/4, 6/8 for 12/4) are given for changing the octave-register in order to combine better with other tones, or metres in this case....the chromatic version of this scale is given at the end of the chapter.

Cowell discusses metrical modulation and bemoans "metrical monotony" on p. 69, in a foreshadowing of the total serialist desire to avoid repetition and introduce continual change:

"The simplest way of using metrical rhythms on the analogy of musical tones is to keep shifting the metrical units in successive measures. If the changes be made, as is often done in the work of Stravinsky, in all the parts at the same time, the result is analogous to a simple melody in tone. To some persons, even so slight a change as this seems unrhythmical and abstruse.... If in lieu of a melody the same note were to be repeated for an entire work, it would be considered absurd; yet this endless repetition is just what is expected in metre, in which hundreds of the same metrical units, such as measures of 3/4, etc., follow one another without change."

He points out examples of composers who wrote irregularly-accented phrases of uneven lengths which lay unevenly across the even metrical bar-lines, yet who never tried writing with changing bar lengths instead. Beethoven's "famous use of sforzando on the weak beats of the measure" is one example, and the syncopation of jazz music is another (in Cowell's day, jazz was basically just what we now call Dixieland).

"What is required to re-create interest in metre is not to do away with so powerful a musical element, nor to keep the bar-lines always the same and then negate them by accents; because accents within the measure are never felt to be the same as first beats in the measure. Neither is it necessary to make of metre a sort of skeleton-in-the-closet, as though it were an evil thing, essential to preserve, but so unlovely that it must be covered by almost any accenting of phrase which will disguise the metrical foundation. All of these devices are interesting in music, but it does not seem amiss to get at the root of the trouble and bring the possibilities of metrical variety up to the same standards now applied to other branches. When metres change frequently, or when harmonies are formed from them, they give pleasure, and it is again of interest to hear them clearly defined, instead of disguised."([p.70])

Cowell eventually considers tempo, the third aspect of musical rhythm, and treats it with harmonic overtone series too. Here, taking MM=24 as a base fundamental, then MM=48 would be the octave, MM=96 the next octave, etc. The interval (ratio) of a fifth is MM=72 against the octave MM=48, the interval of a third is MM=120 against 96, etc. He notes that the base, 24 in this case, is better taken as a very low number, lower than the usual metronome range of 40-208 beats per minute, because that allows higher partials to be used without getting into too high absolute numerical values. MM=24 was taken as the base fundamental just for ease in avoiding fractions in the tempo scale.

This corresponds once again to Stockhausen's example of the construction of a scale of durations by division of the largest unit, because multiplication of metronome tempi corresponds to division of frequency, or duration if the numbers are normalized relative to 1 second, so the scale is shown in our Column 2 of Table 1 in our last section.

Recalling Stockhausen's criticism of the practice, on the part of serial composers, to work with modulations of the base unit of their "subharmonic scales of proportion" in order to avoid excessively long durations that otherwise result from higher duration scale degrees, we note the following from Cowell which describes the practice that Stockhausen described as "inappropriate" in serial music. (Of course, Cowell is no serialist, although he has heard of Arnold Schoenberg's twelve-tone method).

"In this way the key tone of the whole time or metric system can be changed at will, and many simplifications of practice can be made. If, for instance, the rhythmic chord of C (in the ratio of 4:5:6) has been struck, and it is desired to strike the chord of F, this can be done in the key of C only by the use of three-sixteenth notes against three-twentieths notes against eight-notes. If, however, the tempo be changed from MM=96 to MM=64, the chord of F can be expressed by quarter-notes against fifth-notes against sixth-notes, since by means of the change of tempo the key will have been changed to that of F." ([p. 98])

We now consider a final example, Cowell's construction of a chromatic scale with equivalents in metrical length, duration, and tempo. To form rhythmical scales out of the simplest possible ratios, he has to choose small-number overtone ratios to approximate the semitones of a 12-note octave. Here we combine information from his charts found on p. 99, 101, 105, 106, 107 of his book. We are unsure why his C:C octave deviates from the style of the others in that its metrical ratio length is not expressed as a ratio of reciprocals.....also note that in the metrical ratios the fundamental measure is of unspecified variable metre, because otherwise the calculations would get too complicated. That is, since the quantities he is expressing are ratios, they can be given in various equivalent forms (as 1:2 is equivalent to 2:4, 3:6, 11.9:23.8, etc. and the most convenient values for a given situation can be picked from the equivalence classes making up the ratio).

```
Chromatic   Intervals      Ratios    Metrical Ratio       Correspondin
Equivalen  Alterna Tones       From C                   Length (Quarter
g Time Value  t M.M.     te MM.
Notes) Nos.       Nos. C:C        Unison          =1:1      2 = 1-2/4
4th note 48         60                                      measure:1-2/4
C:Csharp    Augmented       = 14:15   210 = 14-15/4        7/30ths note 51
3/7     64 2/7            Unis.                    m.:15-14/4  C:D
Major second    = 8:9     72 = 8-9/4 meas.:     2/9ths note 54         67
```

1/2 9-8/4 C:Eflat Minor third
= 5:6 30 = 5-6/4 meas.: 5/24ths note 57 2/5 72
6-5/4 C:E Major third = 4:5 20 = 4-5/4 meas.: 5th note
60 75 5-4/4 C:F
Perfect fourth = 3:4 12 = 3-4/4 meas.: 3/16ths note 64 80
4-3/4 C:Gflat Diminished = 5:7 35 = 5-7/4 meas.: 5/28ths
note 67 1/5 84 fifth 7-5/4 C:G
Perfect fifth = 2:3 6 = 2-3/4 meas.: 6th note 72 90
3-2/4 C:Aflat Minor sixth = 5:8 40 = 5-8/4 meas.: 5/32nds
note 76 4/5 96 8-5/4 C:A
Major sixth = 3:5 15 = 3-5/4 meas.: 3/20ths note 80 100
5-3/4 C:Bflat Minor seventh = 4:7 28 = 4-7/4 meas.: 7th note
84 105 7-4/4 C:B
Major seventh = 8:15 120=8-15/4 215ths note 90 112
1/2 meas.:15-8/4 C:C Perfect
octave = 1:2 4 = 1-4/4 meas.: 8th note 96 120
2-2/4

He notes that in the duration column, if the fundamental were allowed to vary with the ratio being expressed instead of always being a quarter note, the numbers would be simpler in some cases (i.e. he has done this in the metrical column, but not in the duration column).

For example, if he held the metrical foundation constant to a 2/4 metre measure, then to express the interval C:Csharp, the ratio would be fourteen measures of 2/4, set against fifteen measures of (2-1/7)/(49-255ths) metre.

"This is a metre of 2-1/7, since an accented note will be followed by one and one-seventh unaccented notes. One measure of such metre will contain two 49-225ths notes plus one 7-225ths note, the latter kind of note being one-seventh the length of the former; and the length of time of the whole measure is such that it is contained two and one-seventh times in a measure of 2/4 metre. Both the kind of metre and the length of the measure, then, express the fraction two and one-seventh, which is the correct expression of C sharp, if C equals the number 2....

"The almost insurmountable complexity of this procedure is now sufficiently evident. It would be interesting, though, to hear such rhythms cut on a player-piano roll...." ([p.103])

In the charts, two alternate scales of metronome markings are given, one starting at MM = 48 and the other at MM = 60. The scale starting from 48 yields more fractions as values (for Csharp, Eflat, Gflat, Aflat) than the scale from MM = 60, but the fractions in the MM = 48 scale fall on the "less-used chromatic tones" while the fractions in the MM = 60 scale (Csharp, D, B) include the frequently used notes D (major second) and B (leading tone).

We recall Stockhausen's emphasis, early in his article, on maintaining the fundamental unit of duration constant, in order to make the various ratios among different durations perceptible. We wonder whether Cowell's metrical ratios, with their shifting numerators and denominators, would be possible to implement in actual compositions, and whether they would be perceivable as a harmonic series even if they were composed and performed.

For example, suppose we wanted to perform a "major triad" in his metrical harmony. This would mean three pairs of metres, or six total. Somehow the three individual ratios have to be interpreted, but their collective relationship as a "chord" also has to be expressed.Their lengths are uneven. If they all began simultaneously, some would go on longer than others. We wonder if this is not just an exercise in numerology, just as Backus accused Stockhausen of.

First, for the fundamental, we would need one 2/4 measure set against another 2/4 measure. For the major third, four 5/4 measures are set against five 4/4 measures. For the fifth, two 3/4 measures would be set against three 2/4 measures.

Cowell invoked influences from previous composers to justify his new ideas:

"Although the rhythmical values suggested in the foregoing scales are for the most part new, simpler cross-rhythms, more particularly those formed by different note-durations, have of course been used by many composers. Chopin in notating his rubato improvisations hit on some extraordinary combinations; Brahms developed individual forms of syncopation; Scriabin carried a Chopinesque variety of cross-rhythm a step further than Chopin; Stravinsky utilized irregular metres and cross-accents.

Charles Ives, however, has gone furthest in weaving webs of counter-rhythms. Chords of rhythm are suggested in his works, and he builds up musical moods which rely on musical subtleties to an even greater extent than on tonal elements for their effect." ([p. 108])

To close this paper, we provide anecdotes about Cowell's instrument, the "Rhythmicon", from ([Mead1981]).

Henry Cowell had discussed the possibility of building a rhythm instrument with his friend Henry Varian in 1915-1916, who actually drew up some plans but never finished it. Eventually Leon Theremin built the Rhythmicon. Theremin charged Cowell only $200 to build it, even though he was being offered up to $10,000 from Hollywood studios to build more Theremins, because, according to Mrs. Cowell, "he always enjoyed Cowell and was glad to help him."

The Rhythmicon produced different rhythms which were partials in an overtone series on a rhythmic fundamental (duration), and the pitches produced at each rhythm were the corresponding partials of a pitch series on an audio frequency fundamental. Rhythms of 2 against 1 would sound in an octave, rhythms of 3 against 2 would sound in perfect fifths, etc.

Cowell had written a concerto, called the Rhythmicona, which was to be premiered by Nicolas Slonimsky in Paris in February 1932 but was cancelled and never performed. The instrument was too fragile and difficult to transport to Paris. Charles Ives was financing it, and was also paying for a second one which was to be more like an "instrument" rather than a "machine", as it would have levers and pedals to control the rhythms (one could infer from this that the first instrument was too inflexible in its design to be very musically useful). The second Rhythmicon was never built, however.

The first Rhythmicon was demonstrated at the New School for Social Research in New York on January 19, 1932, along with the Theremin, but most people were more excited by the Rhythmicon because they had already seen the Theremin numerous times before.

Reviewers complained about the limitation in which "one is constrained to represent a single rhythm always upon the same repeated note and without deviation from the regular beat...." (Marc Blitzstein, writing in "Modern Music").

Then it was demonstrated again in San Francisco on May 15, 1932 and was better accepted on the West Coast. But Alfred Metzger, writing in the San Francisco Chronicle, described the rhythmicon's sound as "a cross between a grunt and a snort in the low `tones' and like an Indian war whoop in the high-tones"...

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