On the Horizon of Digital Technics in Kaija Saariaho's *IO* and *Nymphéa*

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AN OPENING: SAARIAHO GOES TO SYMPHONY HALL

On a recent winter's evening I attended the world premiere of Finnish composer Kaija Saariaho's *Saarikoski Songs* (2021), a cycle based on text by poet Pentti Saarikoski that was performed by the Boston Symphony Orchestra with soprano soloist Anu Komsi and conductor Andris Nelsons.[1] The audience warmly received the new work and so too, it seems, did music critics; according to a review the next day in the *Boston Globe*, 'as rendered with Saariaho's distinctive sonic palette, even the most dissonant textures and soundscapes seem no less natural than an improbably gnarled tree'.[2] Similar reviews have been penned about the composer's other recent premieres in the United States, from the *Los Angeles Times* praising her orchestral work *Vista* (2021) as an 'abstract study in the transformation of an ever-shifting musical landscape of melodic shapes, textures, timbres and harmonies',[3] to the *New York Times* heralding a 2016 premiere of *L'Amour de Loin* (2000) at the Metropolitan Opera as 'rich with luminous sounds, astringently alluring harmonies, myriad instrumental colorings and atmospheric textures'.[4] It would appear that, four decades into her career, Saariaho is enjoying a well-deserved moment in the limelight of the North American concert scene.

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Off stage, Saariaho's music has long garnered interest in academic circles, though early research mostly circulated among readers of Finnish and French publications.[5] More recently, there has been a flurry of research in English, including a multi-authored 2011 volume on her life and work, as well as articles, chapters, and dissertations offering more narrowly focused analyses of specific pieces.[6] Much of this scholarship echoes audiences and reviews by emphasising Saariaho's unique sensibility for composing heterogenous textures, radiant timbral effects, and slow-moving processes of continuous transformation. I, too, in my own work, have attempted to shed light on these distinctive features of her music by revisiting their historical provenance, how they emerged in the course of her artistic development, and their connection with an array of compositional tools and techniques developed in the eighties at the Institut de Recherche et Coordination Acoustique/Musique (IRCAM) in Paris.[7] Focusing on early computer-based works – and in particular, an early voice-synthesis study titled *Vers le blanc* (1982) – I have presented a forgotten audio recording to demonstrate the over-looked role of speech phonemes as a generative model for the composer's turn to spectral harmony. Additionally, I have excavated old synthesis code to show how her method of composing continuous processes of 'interpolation' was grounded in the affordances of contemporaneous IRCAM technologies like the CHANT and FORMES programs. Here, I want to build on these observations by tracing associations between Saariaho's early adoption of electronic-digital studio techniques and her novel approach to writing for acoustic instruments in two later works from this period: *IO* (1986–1987) for sixteen musicians, tape realised by computer, and live electronics; and *Nymphéa* (1987) for string quartet and live electronics. The former was composed for the occasion of IRCAM's tenth anniversary, while the latter was written for the Kronos Quartet and ranks as one of the composer's most often performed works. Together, they mark the culmination of a formative five-year period in Saariaho's career, acting as a milestone that confirmed her aesthetic identity and foreshadowed her rise as an internationally renowned composer.

In what follows, I begin with a brief biographical sketch of Saariaho's move from Finland to France, reconstructing her initial encounters with spectralism and computer-based composition. I then pivot to analyse excerpts from *IO* and *Nymphéa*, drawing on archival materials from IRCAM and the Paul Sacher Foundation, including preparatory sketches, form diagrams, fair-copy scores, archived computer programs, and documentation for digital applications used in live performance.[8] Translating between these varied artifacts, I show how Saariaho used acoustic models to generate sounds at the threshold of harmony and timbre, and I detail how she created linear interpolations to move between musical patterns, thereby extending two important techniques found already in

Vers le blanc. I conclude by considering how the obsolescence of tools used in the creation and performance of these works necessitated their remediation as part of a visual programming environment in the early nineties. The overall picture that emerges is one in which Saariaho constructs a compositional method in the confines of a computer program, applies it to purely instrumental settings, then adapts it to a changing software environment to ensure that it remains viable in live performance. My analysis frames this externalization of musical practice in relation to the concept of *technics* which, as the late French philosopher Bernard Stiegler theorised it, comprises a generalised mix of technologies, techniques, and cultural relations concretised in the form of a technical system.[9] Crucially, such systems are both material and temporal, acting as containers for historical memory while also setting limits on what can be remembered, and by extension, imagined. Writing, phonography, cinema – these media don't just store representations of the past; their material forms inflect collective memory of that past, granting selective access to some moments and not others. For this reason, Stiegler's work is useful not only for connecting the technics of Saariaho's compositional method with the experience of listening to her music, but for understanding some of the challenges facing digital preservation efforts at places like IRCAM. All the more so because Stiegler once served as director of the institute (2002–2006), where he took an interest in establishing a 'digital sound archive', applying his theoretical ideas on *hypomnēsis* to the practical context of a multimedia library system.[10] Considering these dual aspects of his work in parallel points to the possibility of a larger project on turn-of-the-century technics and media-in-transition at IRCAM, while also bringing into sharper focus the ways in which Saariaho's musical style has developed in dialogue with an emergent technocultural milieu centered around psychoacoustic research and computer science.

FINLAND TO FRANCE: 'LIBRE COURS DU SOUFFLE, ESPRIT OUVERT, RECHERCHE DU NOUVEAU'

Although Saariaho is a Finnish composer, she has lived in Paris for decades and her work is deeply intertwined with musical life at IRCAM. She arrived in Paris, in January 1982, by way of Freiburg, and prior to that Helsinki, where she studied for several years with Paavo Heininen at the Sibelius Academy. It was under the tutelage of Heininen that Saariaho began honing her compositional method. In an early essay titled 'Cry if you want, but fly!' (1980), she reflected on their time together, saying: 'it is impossible to exaggerate the importance of his teaching on my slow evolution towards a deeper consciousness and on my ability to take into

account several simultaneous options–the aerial perspective and (I want to express it thus) the free flight'.[11] This elevated perspective allowed the young composer to refine her aesthetic vision, which she pegged to three artistic ideals: 'free flowing breath, an open mind, and a search for newness'.[12]

Saariaho's commitment to these forward-looking ideals was bolstered in 1978 when she visited the Darmstadt festival and heard a wide range of avant-garde music that was for the most part inaccessible in Finland.[13] Her education soon precipitated a move to Freiburg, where she studied with Klaus Huber and Brian Ferneyhough, immersing herself in a school of post-serial pedagogy that turned out to be largely incompatible with her own aesthetic sensibilities.

> I was immediately in this extremely post-serial school. And I realized – well, I knew already – that this was not what I wanted. These guys were drawing these unbelievable diagrams on the blackboard, systems, and interactions, and all of that – and what did you hear of it in the music? All of that complexity, for what aural result? It was kind of a crash course to get me out of that whole thing.[14]

Saariaho found an answer to the impenetrable complexity of post-serial music when she encountered French spectralism at the 1980 Darmstadt festival. She was immediately drawn to its foregrounding of sound's sensuous effects and processes, as well as its revolt against post-serial dogma:

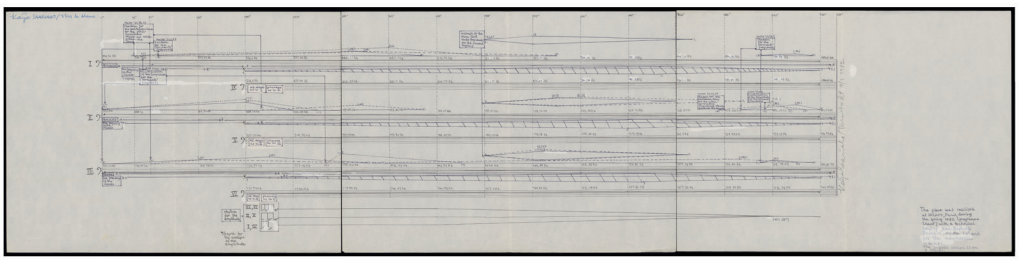
> […] the first time I heard Tristan Murail's and Gérard Grisey's music – that was fantastic! I will never forget the effect it had on me. Their music was not played in Scandinavia and it was not even recorded – well, there was one record, but it had not reached us up there. It sounded so fresh, it was just unbelievable. We had had this post-serial education, where octaves are forbidden even in an orchestral context, and Grisey's and Murail's music just sounded so good.[15]

Two years later, guided in part by her interest in spectral music, Saariaho left Freiburg for Paris to enroll in a computer music course taught by Xavier Rodet at IRCAM. While there, she learned about psychoacoustics and the use of synthesis programs as a mode of composing not just *with* sounds, but rather, the sounds themselves. The course focused on the newly developed CHANT program for voice synthesis,[16] equipping Saariaho with tools that proved central to the realization of *Vers le blanc* in Spring 1982, ahead of its premiere later that year at the Darmstadt Summer Courses for New Music. Afterward, Saariaho continued working at IRCAM, collaborating on research projects with psychoacoustician Stephen McAdams and on creative projects with software developers such as Xavier Rodet, Jean-Baptiste Barrière, and Jan Vandenheede.[17] Through these collaborations, connective tissues between science and art were made explicit,

with the interests of different disciplines woven together in a common pursuit of shared knowledge and tools, albeit applied toward different ends. Like Hermann von Helmholtz and his electro-magnetic tuning-forks, or Homer Dudley and the electronic Voder at Bell Labs, the research team at IRCAM in the early-1980s was invested in CHANT as a way to study the individual elements of vocal timbre in a more controlled environment. Composers, meanwhile, used the same software as a means to greater control over the microsonic aspects of sound, and to achieve interesting musical results more easily than was possible with earlier programs like MUSIC V. Thus, for scientists and artists alike, a didactic feedback loop emerged, with both types of users alternating between analysing, synthesizing, and listening to sounds as they formalised their understanding of vocal timbre within a horizon of digital technics defined by the program's interface.

Despite her early disavowal of post-serialism, Saariaho never fully relinquished a fascination with strict ordering procedures. In *Vers le blanc*, she would harness the CHANT program's use of 'breakpoint functions' – i.e., a series of value-time pairs graphing a linear trajectory – to define temporal processes, relaying this technical feature into a broad methodological framework for controlling not only pitch and rhythm, but vibrato, tremolo, harmonicity, and other sonic parameters.[18] Shown in FIGURE 1, evidence of this framework is found in a form diagram at the Sacher archives, in which Saariaho charts sub-note processes for each of six voices, providing a blueprint to the piece's underlying timbral transformations.[19] Because I have already examined the diagram's interpolative logic and underlying code elsewhere, I will not rehearse the details here. But it is important to note how each parameter proceeds along an independent path connecting discrete value-time coordinates within CHANT's temporal infrastructure, as well as the way these disparate lines come together to shape the music in both its micro- and macro-formal dimensions. Moreover, it is important to highlight references to 'phonemes' in the diagram; these hint at Saariaho's interest in spectral models, which she treated in a pseudo-serial manner, ordering them into nested groups that coalesce in a large-scale palindromic form. The models themselves were sourced from a dictionary in CHANT, where each phoneme was defined by a spectral shape containing five prominent peaks (aka, 'formant regions'). Saariaho's use of these readymade voice models foreshadowed her later method of recording and analysing instrumental sounds as a source of harmonic and timbral generation. Likewise, her application of interpolations to different sonic parameters facilitated the production of a 'multilevel network of continually changing but controlled items' that is today deemed a hallmark of musical form in her compositional aesthetic.[20]

FIGURE 1. Saariaho, *Vers le blanc* (1982), form diagram. Kaija Saariaho Collection, Paul Sacher Foundation (Basel).



Returning to the early days of IRCAM provides a glimpse into the formation of Saariaho's aesthetic, and in particular, its articulation to programs like CHANT. It was not long after *Vers le blanc*, that she used CHANT and a companion scheduling program, FORMES, to develop a customised subroutine called 'transkaija'.[21] First, she outlined the program's basic conception in a pair of papers delivered at the *International Computer Music Conference* in 1983 and 1984.[22] Then, in a 1988 IRCAM report detailing the creation of *IO*, she and her technical assistant, Jan Vandenheede, officially dubbed the program as 'transkaija' and described its function in greater detail:

> The other important software is the program 'transkaija', which was designed by the composer in 1984 and has been used in different pieces since then. The central idea is the notion of interpolation. We give the program different patterns, lists of associations for the elements of successive patterns, and evolution curves between these patterns. Patterns can be applied to different parameters and have different lengths […] the elements can divide or merge.[23]

Here, we have a description of composition as a generalised technical system. References to 'patterns' comprised of 'elements', with 'lists of associations' and 'evolution curves' defining motion in between – these are the properties of an abstract process that could be applied to any sonic parameter at any level of musical structure. The unifying thread is numerical representation: anything that can be assigned a value can be controlled in a similar fashion, so the same processes used to control macro-events like phrase structure can be applied to micro-events like amplitude envelopes for the individual sinusoids within a spectrum. Saariaho thus crystallised a general theory of interpolation in the algorithms of 'transkaija', forging a new compositional tool to build increasingly elaborate formal processes in works like *IO* and *Nymphéa*. Through this exchange, her music became entangled with digital technics at IRCAM, further solidifying her move from Finland to France and her turn from post-serialism to a more loosely defined post-spectralism.

ANALYSING INTERPOLATIONS AND SOUND MODELS IN *IO* (1986–1987) AND *NYMPHÉA* (1987)

Saariaho's program note for *IO* describes the work as a 'synthesis of earlier experiences, above all *Lichtbogen* (1986) and *Jardin secret II* (1985–1986)'.[24] The former piece for nine musicians and live electronics marks an important breakthrough in the composer's extension of studio-based techniques to acoustic instruments, and it has been analysed at length in several studies;[25] the latter for harpsichord and tape with computer-processed audio stands out for its intricate use of interpolations, a feature I detail in my own prior analysis.[26] Together with another piece from this same period – *Jardin secret I* (1984–1985) for computer-generated sounds alone, which Saariaho described as the 'first étude in a series of works' premised on the concept of 'a gradual interpolation between two points, realised on different parameters in different scales'[27] – these early IRCAM engagements acted as a creative catalyst, allowing the composer to explore various facets of electro-acoustic/ digital composition and hone necessary programming skills.

Building on these precedents, *IO* represents a significant advance in Saariaho's efforts to blend her instrumental writing with a compositional method that had been formalised on the computer. Especially compared to *Vers le blanc*, the piece's rich palette affords greater opportunity for textural depth and complexity, while its larger form (ca. eighteen minutes) permits ample space to organise more intricate interpolations. The overall structure is characterised by an onion-like layering of nested processes, one within the other, moving at different speeds, sometimes synchronised and sometimes not, yielding a dense tapestry of processual shapes. Saariaho describes the intended effect as a 'three-dimensional space in which timbres and textures composed of fine layers, more or less transparent, rest one on top of the other'.[28] In this way, divisions between sections are clouded by overlapping textures that saturate the foreground, making it difficult to pinpoint beginnings, middles, and ends. The outcome is a fluid ebb and flow between sections, a kind of dynamic homeostasis where everything is always adjusting, yet nothing seems to change.

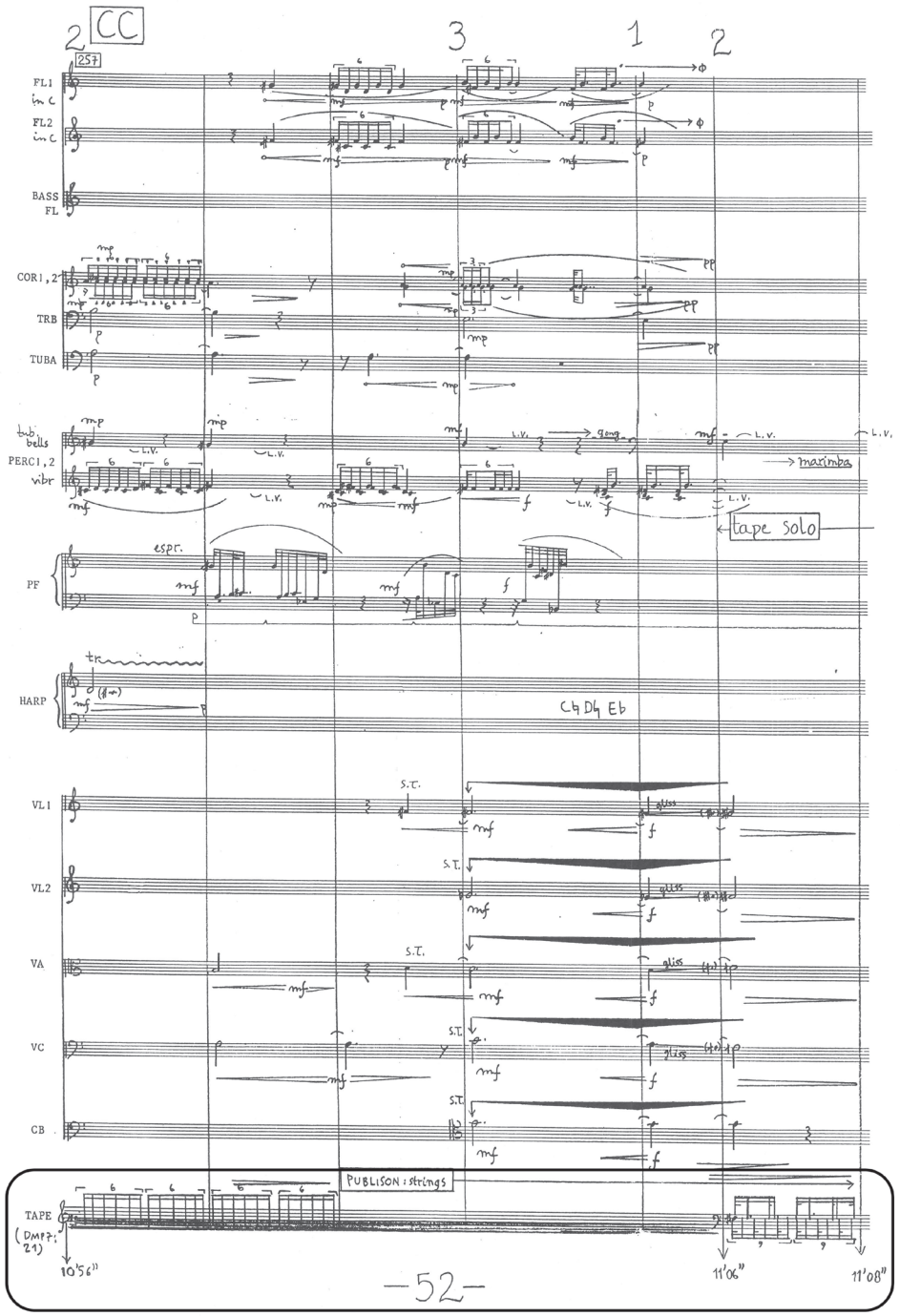
Despite its prevailing sense of formal ambiguity, *IO* contains several guideposts to orient the listener. Two tape solos act as natural boundary points; the last of these (m. 281, ca. 11' 45") stretches for nearly three minutes, growing into a self-contained section, whereas the first lasts only a minute and brings closure to the work's opening section. More generally, the form is governed by oppositions in a range of sonic domains. Many of these oppositions, such as the sound-noise axis or the harmony-timbre continuum, are mainstays of Saariaho's aesthetic and have been addressed in her writings. Others have been mentioned less often but are equally important to the establishment of large-scale formal networks – these

include pairings like *vibrato* vs. *senza vibrato*, *sul tasto* vs. *ponticello*, and *forte* vs. *piano*. Saariaho grew accustomed to controlling these types of variables in a precise manner thanks to her work with the CHANT program. Moreover, through her subsequent experience programming in the combined CHANT-FORMES system, she learned to negotiate relationships between these variables by integrating them within a larger model of organization and sound generation. For her, individual elements like vibrato ceased to be part of implicit stylistic conventions, as is still the norm in performances of common practice music; instead, they were regarded as dimensions of the overall sound to be determined by the composer. By exerting careful control over aspects like vibrato and bow placement and pressure, Saariaho imported a synthesis-like mindset to her instrumental composition, extending models inherited from the CHANT-FORMES system.

As with previous works, the movement between opposing pitch and rhythm patterns in *IO* is achieved through interpolation processes that unfold along a linear trajectory of breakpoints. The music features a pervasive use of interpolations in different parameters and goes far in developing these processes; for instance, by layering multiple streams of processual action that evolve at different paces, or temporarily interrupting a process and then resuming it, or nesting local processes within a larger metaprocess. I will focus here on a passage that clearly demonstrates Saariaho's refinement of rhythmic interpolations. The excerpt in FIGURE 2 occurs near the end of the piece, at a point when the tape and live ensemble participate in a back-and-forth exchange of musical roles.

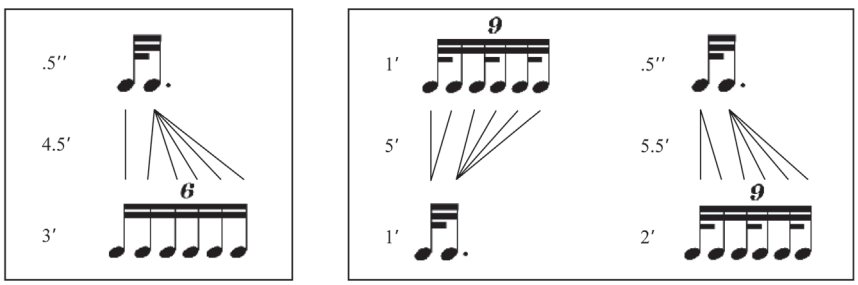
The tape part at m. 257 (FIGURE 2, bottom staff) picks up at the end of a rhythmic interpolation begun in the previous bar, in which a dotted duplet rhythm gradually accelerates and transforms into even sextuplet sixteenth notes. This same sextuplet pattern then appears in the winds and percussion, which proceed to reverse the interpolation, gradually slowing and transforming the sextuplets back into a dotted-rhythm motive at m. 261 (e.g., see vibraphone). By then, another tape solo interjects with a new pattern and begins another back-and-forth exchange of rhythm interpolations. In fact, the passage above kickstarts a long-range process, in which three additional tape solos (mm. 262–267, mm. 268–273, and mm. 274–278) pose a series of interpolations leading to a longer, cadenza-like tape solo at m. 281. During each segment, the tape executes a quick transformation, advancing the process to its next ostinato zone, where the ensemble overtakes the harmony-rhythm pattern and dissolves its momentum. Along the way, temporary holdover spots are nested within the overall evolution of patterns, providing nodes of connection where the ensemble synchronises with the tape. I have been unable to locate the precise code for this passage, but evidence of a programmed rhythmic interpolation exists in the form of penciled-in notes on a fair copy score at the Sacher archives.

FIGURE 2. Saariaho, *IO pour 16 musiciens, bande réalisée par ordinateur, et electronic-live*, (1986–1987), score, mm. 257–262.



Specifically, at m. 256, there are references to file names ('son11.ll' and 'seq.11'), as well as hand-drawn reduction diagrams charting interpolations between rhythm patterns. Outlined in FIGURE 3, Saariaho's reduction divides the interpolation into successive phases; in the first, an initial dotted rhythm is gradually altered over the course of five seconds until it locks into a sextuplet configuration for three seconds. In the second, governing the next five bars (mm. 262–267), two rhythm patterns are presented simultaneously before undergoing an exchange of their various elements through parallel interpolation processes lasting seven and eight seconds, respectively. As a result, one voice progresses from a dotted-nonutuplet rhythm toward the original dotted rhythm, while the other runs in the opposite direction.

FIGURE 3. Saariaho, transcription of jottings on fair copy score of *IO*, mm. 256–267. Kaija Saariaho Collection, Paul Sacher Foundation (Basel).



In many respects, the interpolations in FIGURE 2 recall those in *Jardin secret II*, where the harpsichord and tape take turns directing multi-stage interpolation processes. But here, there are more variables at play. Marshalling the timbral possibilities afforded by a large ensemble, Saariaho balances the rhythm interpolations in this excerpt against varied dynamics and articulations in the winds, as well as a sound-noise axis in the strings, achieved through alternating bow placement and pressure (e.g., *sul tasto* markings and thickening brackets above strings at m. 260). These timbral elements bolster points of contact between the tape and ensemble, and they complement Saariaho's live-electronics processing, merging with subtle effects like reverb, delay, and harmonization that treat instrumental sounds on their way to diffusion through loudspeakers.

Beyond its extensive utilization of interpolations, *IO* is noteworthy for incorporating another novel compositional technique: the analysis of acoustic models for automatic transcription. The technique was facilitated by the CRIME environment running the IANA application, a piece of software designed at IRCAM in the early eighties by Gérard Assayag. Functionally, the IANA application combined

fast Fourier transform (FFT) analysis with an algorithm developed by Ernst Terhardt to extract tonal components, evaluate masking effects, and determine the perceptual saliency of frequencies in a given spectrum.[29] In this way, it sought to model auditory perception, encoding an idealised listener at the heart of the algorithmic process. The perceptually coded results provided Saariaho with a basis for writing harmonic structures that verged on the threshold of timbral fusion, thus extending the manual *instrumental synthesis* techniques employed by Gérard Grisey and other first-wave spectralists in the preceding decade. By the mid-nineties, a real-time implementation of the IANA algorithm would be developed by Todor Todoroff and Eric Daubresse for use in an IRCAM-commissioned work by Joshua Fineberg (*Empreintes*, 1995), and the algorithm still exists as part of the 'Max Sound Box', a collection of real-time interaction modules that can be purchased on the IRCAM Forum website.[30]

FIGURE 4 shows Saariaho's IANA analysis of a contrabass playing tremolo on a low E^1, one of a few sounds used as source material for harmony in *IO*. The top staff transcribes higher frequency components detected in the signal (i.e., 'partials'), with a three-tiered series of numbers below each pitch denoting (from top to bottom): a) deviation from equal-temperament tuning, measured + or – 50 'cents' from the notated pitch; b) relative amplitude of each pitch, measured 'on a scale of 0 to 1000'; and c) using this same scale, the perceptual salience attributed to each pitch by Terhardt's algorithm (i.e., 'perceptual feet').[31] Reflecting the results of this reduction process, on the bottom staff, we find only those pitches deemed important by the program, yielding an eight-note set that harbors potential for fusing into an inharmonic, string-like timbre evocative of the underlying contrabass model.

FIGURE 4. Saariaho, IANA analysis of double bass used in *IO*.[32]

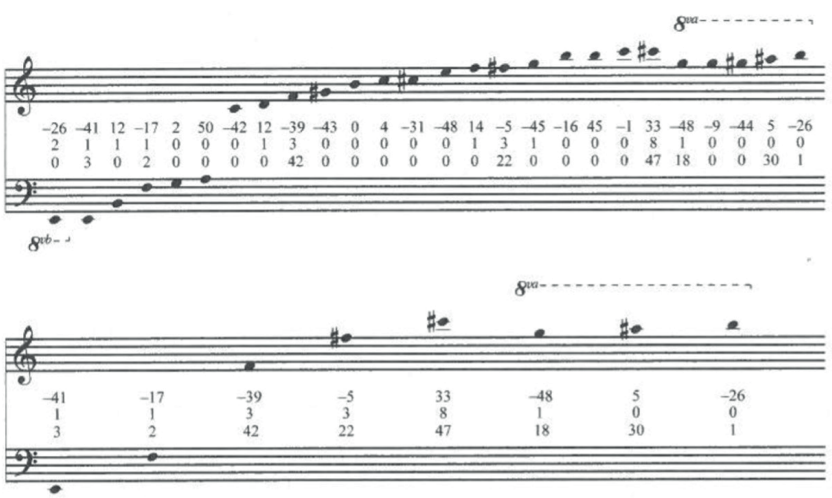
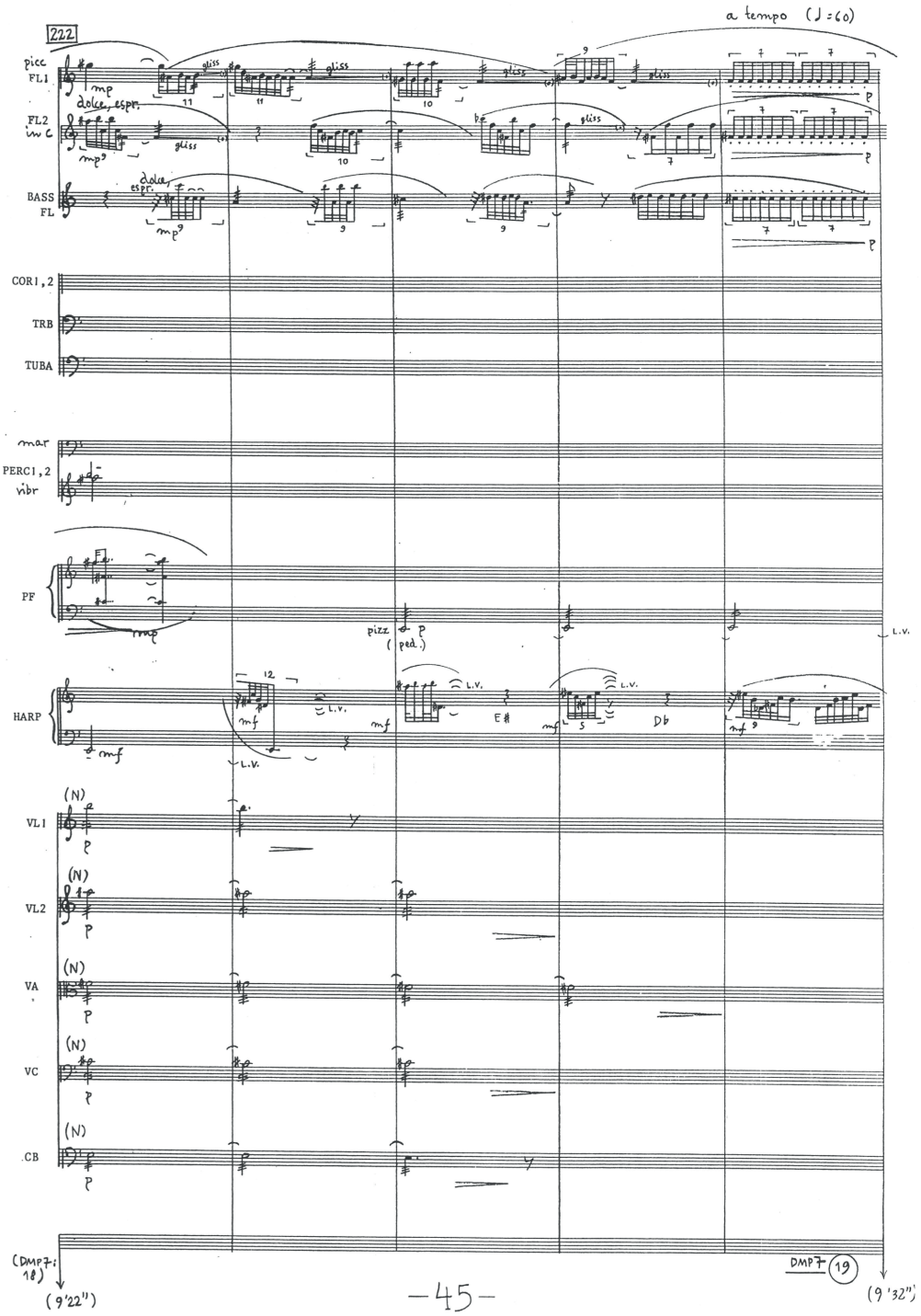


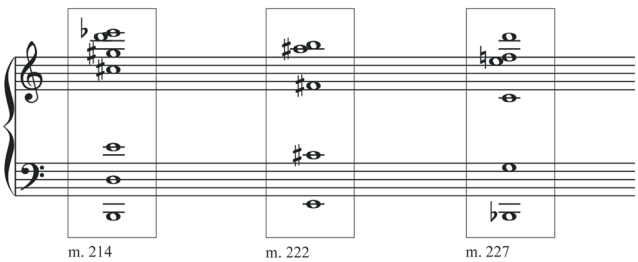
FIGURE 5. **Saariaho, *IO*, score, mm. 222-226.**



Saariaho used the model above as a source of harmonic generation at mm. 222–226 (FIGURE 5), where the contrabass sustains a lowered E^2, presenting a variation of the model itself alongside a registrally reduced voicing of partials $C\sharp^4$, $F\sharp^4$, $A\sharp^5$, and B^5 in the upper strings. Against this fixed texture, the woodwinds produce a mesh of interwoven gestures, consisting of varied articulations and rapid oscillations between upper partials that were deemed less salient by Terhardt's algorithm. Over the next five bars, each disparate layer of the woodwind texture gradually narrows its ambitus, with bass flute, flute, and piccolo settling on the more salient pitches $C\sharp^4$, $F\sharp^4$, and F^5 by the end of the passage (m. 226). In parallel with this reduction of pitch information, the initial display of rhythmic variety is reduced, as each instrumental layer converges on septuplet sixteenth notes performed with a uniform staccato articulation and tapered dynamics. The combined effect is of a spectrally fused harmony emerging in the strings and then melting away through interpolation processes in the woodwinds.

The excerpt in FIGURE 5 is part of a larger harmonic progression that appears to be based on analyses of different sound models. Zooming outward, FIGURE 6 presents a score reduction of the surrounding string harmonies in mm. 214–237. The first, which occurs in mm. 214–221, corresponds with an IANA analysis document at the Sacher archives dated October 11, 1986 and titled 'u1/research/kaija/IANA/soufharm2c'; the last, occurring in mm. 227–237, corresponds with a different IANA document dated November 4, 1986 and titled 'u1/research/kaija/IANA/low-doa'. It is not known which sounds were analysed, but in contemporaneous notes, Saariaho lists several models, including contrabass, cornet, and flute, each playing a range of articulations (e.g., tremolo, trills). These sources likely provided a general vocabulary of spectral structures that were translated into the score, though in a flexible fashion, with microtonal modifications and octave displacements made to suit preferences of style and instrumentation. For the extended passage in question, all pitches in the strings were either salient in the IANA analyses or else hand selected by the composer, who annotated the transcriptions by circling and assigning her own values to certain pitches.

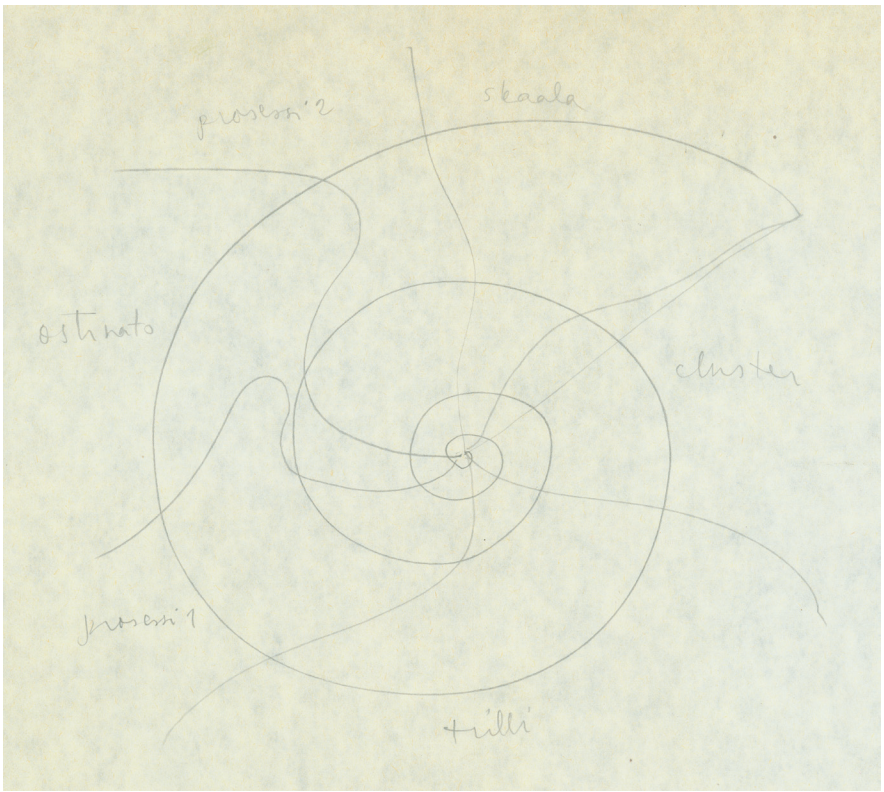
FIGURE 6. Score reduction of string harmonies, *IO*, mm. 214-237.



I will return to *IO* at the end of the article, but first, it is worth investigating in greater detail how similar compositional models and interpolation methods were deployed in the *Nymphéa* string quartet. Written not long after *IO* was completed, *Nymphéa* remains one of Saariaho's best-known works. It was originally commissioned by the Kronos Quartet and persists as a perennial pillar of new music programming, having been performed and recorded by numerous ensembles, including the Kronos Quartet (2013), Meta4 (2013), and Cikada Quartet (2005). In the program note, Saariaho states: 'I continue the approach towards string instruments that I used in my earlier works *Lichtbogen* and *IO* and also develop musical processes through the use of the computer and my specific computer programs (the subtitle of the piece *Jardin secret III* describes this, connecting it to a series of similarly named works)'.[33] Indeed, the quartet shares many similarities with these early prequels: if *Jardin secret I* immersed Saariaho in a digital world of synthesis and linear breakpoint functions, and if *Jardin secret II* facilitated her extension of these techniques to a tape-plus-solo-instrument configuration, then *Nymphéa (Jardin secret III)* represents a culmination of sorts, marking her integration of previous experiments into the cohesive bounds of a venerable classical music genre, the string quartet, as well as her further extension of approaches from the studio into live-performance settings through a targeted use of real-time, interactive technologies.

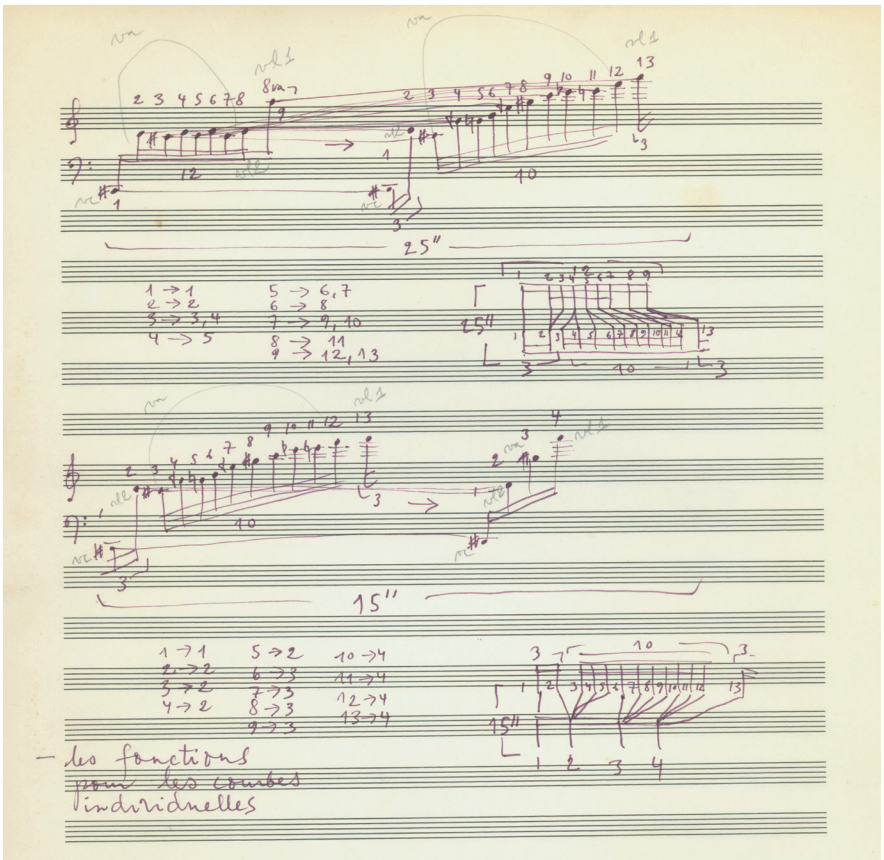
Aside from its subtitle, the quartet shares its overall form with *Jardin secret II*, as both pieces are based on the same basic shape: a spiral. Illustrated in a series of striking sketches at the Sacher, one of which is reproduced in FIGURE 7, Saariaho conceived the work's form as a spiral divided into sections associated with six different types of musical material, including 'cluster, trill, process 1, ostinato, process 2, and scales' (read clock-wise).[34] The process-oriented sections of this form feature interpolations between fixed patterns in various parameters, whereas the other sections are more stable. Moving outward from the center of the spiral entails progressing in a cyclic fashion through the various sections, which grow longer at each pass, establishing a long-range process of formal expansion that is palpable upon listening. Gérard Grisey once described this kind of lengthening process as an act of 'temporal suspension', likening the effect to the structure in Werner Herzog's film *Aguirre, the Wrath of God* (1972), which features a 'continuous slowing down, the events becoming fewer and further apart until the end, even as the tension of the viewer grows'.[35] This is an equally apt description of what happens in *Nymphéa*, where each passing refrain stretches over increasingly long distances, leading the listener into evermore spacious terrains.

FIGURE 7. Saariaho, *Nymphéa*, spiral diagram dated May 22, 1987. Kaija Saariaho Collection, Paul Sacher Foundation (Basel).



The prevalence of interpolations in the processual passages of *Nymphéa* frequently gives rise to multilayered textures made of shifting harmonic patterns, but the same breakpoint logic can be applied in a melodic context. In Saariaho's notes and sketches, there is evidence of such applications. Shown in **FIGURE 8**, hand-drawn diagrams depict mappings between different pitch and rhythm structures, with lines connecting the individual elements of each group. On top of the page, four notes constitute the initial pattern ($D\sharp^2$, $C\sharp^4$, D^4, A^6), which is then mapped onto thirteen notes in a second pattern ($D\sharp^2$, $C\sharp^4$, D^4, $G\natural^4$, G^4, B^4, $E\natural^5$, $G\sharp^5$, C^6, $E\flat^6$, E^6, F^6, A^6). Below, timings indicate how this few-to-many mapping takes place over twenty-five seconds, and afterward, how the process is reversed through a many-to-few mapping that lasts fifteen seconds before settling on another four-note collection ($D\sharp^2$, D^4, $G\sharp^5$, A^6). Crucially, the primary motion between patterns happens in the viola, which expands from a semitonal dyad ($C\sharp^4$, D^4) to an eleven-note set ($C\sharp^4$, D^4, $G\natural^4$, G^4, B^4, $E\natural^5$, $G\sharp^5$, C^6, $E\flat^6$, E^6, F^6), while the other strings remain fixed.

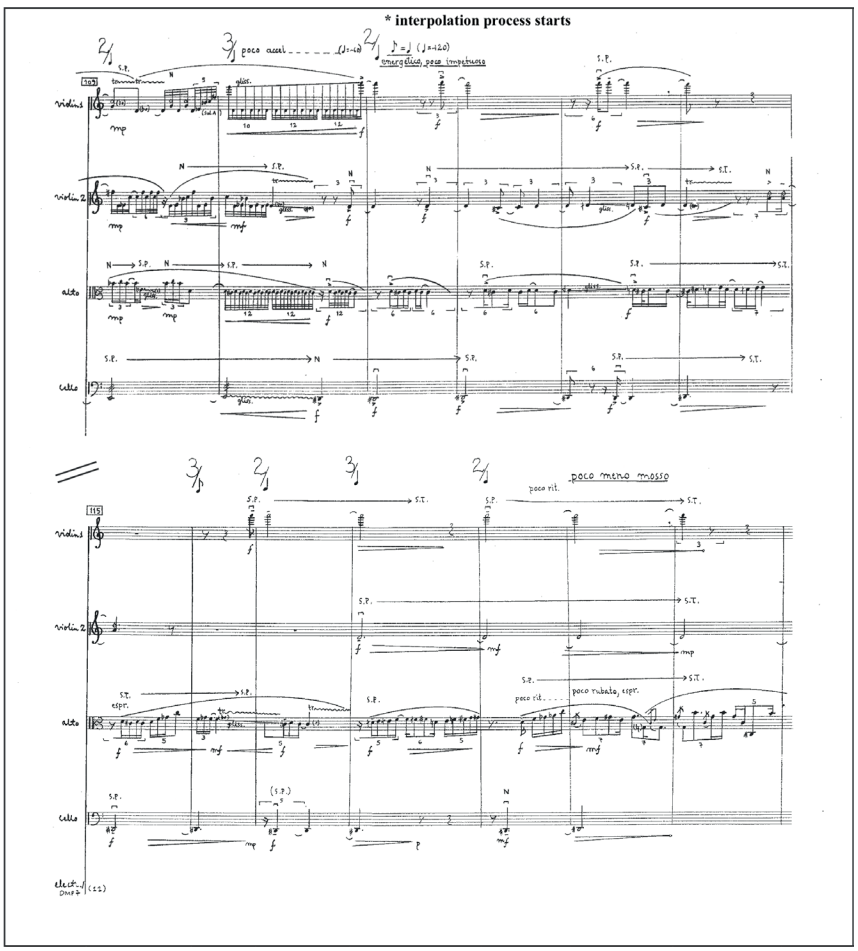
FIGURE 8. Saariaho, *Nymphéa*, sketch for interpolation process. Kaija Saariaho Collection, Paul Sacher Foundation (Basel).



The two-part interpolation in FIGURE 8 corresponds with mm. 111–148 in the final score; the beginning of this process (mm. 109–121) is pictured in FIGURE 9. Notice how the cello and first violin sustain $D\sharp^2$ and A^6, respectively, while the second violin oscillates between $C\sharp^4$ and D^4, and the viola embarks on a solo journey that gradually expands in pitch space. The latter juxtaposes scalar figures with trills, glissandi, grace notes, varied articulations, and special bowing techniques to produce a mercurial melody, which grows in complexity and culminates with an eleven-note flourish at m. 127. Afterward, the viola's range is reduced to a single pitch as the solo recedes into another four-note set at the fermata in m. 131 ($D\sharp^2$, D^4, $G\sharp^5$, A^6). This moment marks the completion of both the viola solo and the two-part interpolation outlined in FIGURE 8, but a brief reprise of sorts then follows. In mm. 134, additional instruments join the viola with their own melodic lines, producing a rich contrapuntal texture that is, once again, comprised of pitches

from the full thirteen-note set heard a few bars earlier. We are instantly thrust back into the middle of the previous interpolation, setting up a replay of the many-to-few mapping, except now each instrument arrives at mm. 146–148 on a different pitch of the final four-note set.

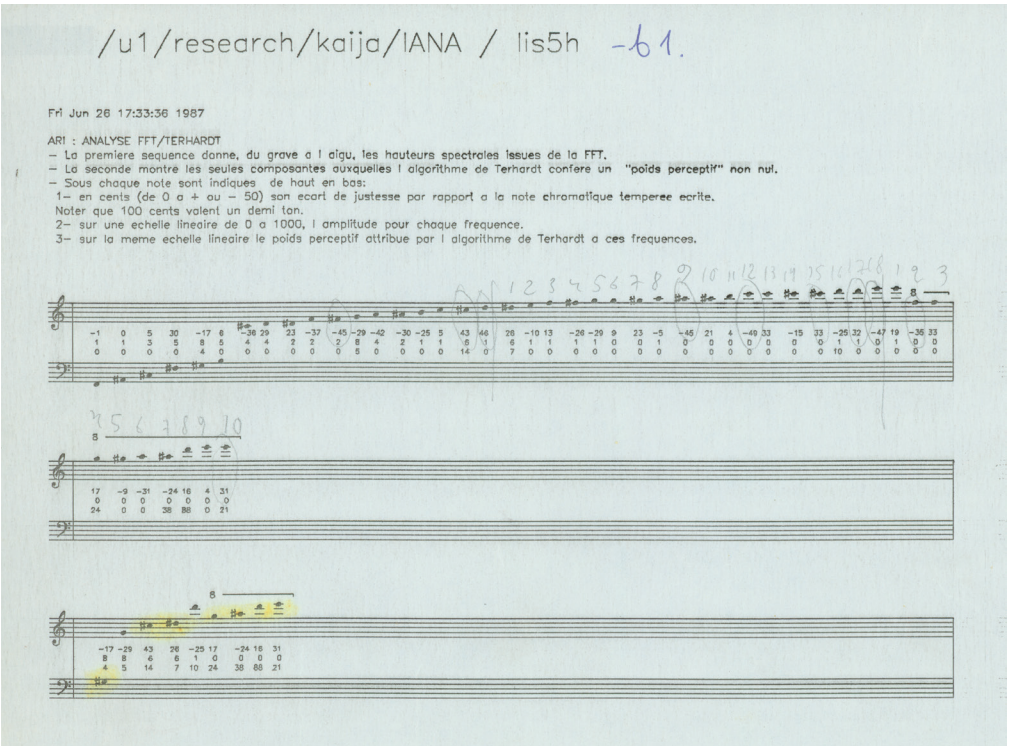
FIGURE 9. Saariaho, *Nymphéa*, score, mm. 109–121.



Like its predecessor, *IO*, the harmonic language of *Nymphéa* can be linked to the use of IANA software to analyse and then instrumentally re-synthesize recorded sound models. In the program note, Saariaho confirms that 'the basis of the entire harmonic structure is provided by complex cello sounds that I have analysed with the computer',[36] but it is unclear how many cello recordings were used and what their exact sonic properties might have been, since only three IANA analyses are contained in the archived collection for this work. Saariaho might have created and

deployed additional models in the compositional process, which have since been lost or misplaced. Among those remaining, however, the IANA analysis reproduced in FIGURE 10 – dated June 26, 1987 and titled 'lis5h-b1' – corresponds with a few different passages in the final score, including mm. 263–267, shown in FIGURE 11.

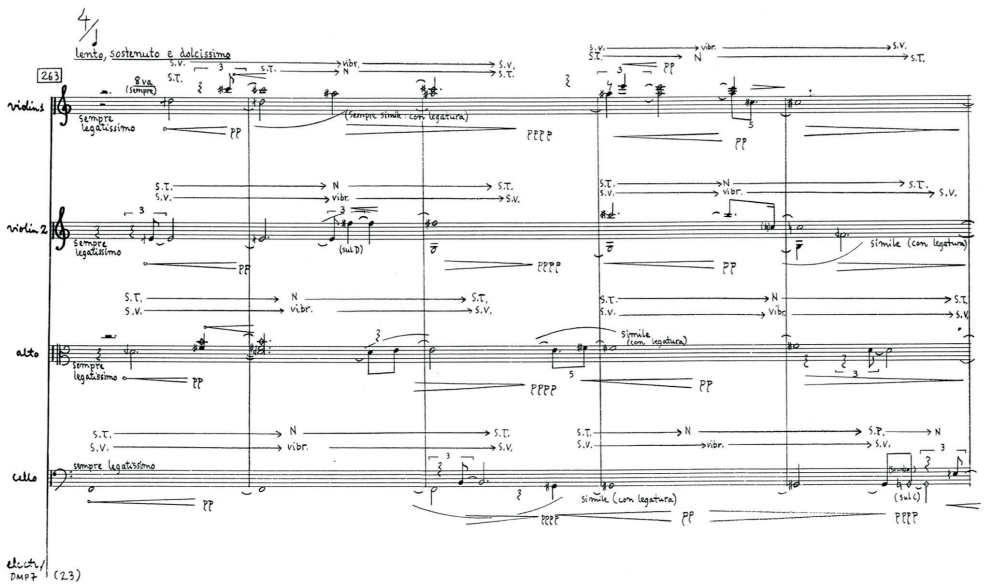
FIGURE 10. Saariaho, IANA analysis with annotations. Kaija Saariaho Collection, Paul Sacher Foundation (Basel).



Comparing FIGURES 10 AND 11, it is clear the IANA analysis did not determine harmony, so much as it provided a loose reservoir of pitches that Saariaho used freely at her discretion. As in FIGURE 4, the software analysed each of the upper partials contained in the acoustic model, assessing their deviation from equal temperament in cents, relative amplitude, and perceptual salience. The nine-note set on the bottom staff isolates partials that were judged most salient, but notably, Saariaho also hand-selected pitches left out of the final IANA analysis, drawing circles around several noteheads on the upper staves ($F\sharp^4$, $C\sharp^5$, D^5, $A\sharp^5$, C^6, $C\sharp^6$, D^6, F^6, E^7). The harmony in the final score (FIGURE 11) is derived from this subset of pitches, again with slight microtonal adjustments, enharmonic respellings, and registral displacements. The only exception is the cello at mm. 263–265, which

grounds the composite spectrum by stating the F^2 fundamental of the original sound. Upper strings then act as a spectral filigree, emerging with a slow rotation of partials, played at a whisper and with nuanced timbral shadings produced by alternating bow placement (*sul tasto* v. *sul ponticello*), selective vibrato, and occasional use of harmonics. This passage occurs after a dramatic grand pause – the only one in the work's entire, single-movement form – which clears space for a glacial procession of overlapping harmonic fields over the next thirty-three bars. The experience of forward motion here turns out to be illusory, however, as nearly all of the pitches in the hushed string texture can be traced back to the IANA analysis in **FIGURE 10**.

FIGURE 11. Saariaho, *Nymphéa*, score, mm. 263-267.



The analysis of archival sketches for *Nymphéa* enhances existing accounts of the work, such as that of Michael Rofe, who analyses its temporal form in terms of the problems it poses for teleological listening.[37] What Rofe describes as an 'expansion of pitch space', we might now understand as resulting from the kind of interpolation processes represented in **FIGURE 9**. Likewise, his breakdown of the 'growth, life, and decay' of multi-layered textures in the work can be heard as intensive processes of interpolation unfolding in multiple parameters simultaneously. And his arguments around the symmetry of form in *Nymphéa*, which he pegs to the varied recurrence of familiar sonic gestures and processes, can now be expanded with reference to the composer's spiral diagrams, where a handful of sound types are brought back

in a recursive series of elongating cycles. Linking score-based analyses to archival sources in these ways has the potential to deepen our appreciation of Saariaho's early music, providing insights into her adoption of acoustic models as a source of spectral harmony and her development of a generalised interpolation system (aka 'transkaija'). Knowledge of these techniques is indispensable for analysing subsequent works from this period, such as *Petals* (1988) for solo cello with live electronics, which features the same form and content as *Nymphéa*, as well as more recent works, like *L'amour de loin*, for which 'the notion of interpolation is essential for understanding certain sonic textures'.[38] Indeed, as this last example suggests, Saariaho's use of the same techniques has persisted despite the introduction of novel programming paradigms and real-time performance technologies, raising the question of how she manages the adaptation of her work to a rapidly changing media landscape.

TOWARDS CLOSURE: REMEDIATING TOOLS AND TECHNIQUES IN THE DIGITAL ATELIER

The late eighties were a period of rapid technological transition at IRCAM, with legacy software like CHANT and FORMES being overtaken by a new generation of visual programming languages like 'Patchwork' and 'The Patcher', forerunners to the OpenMusic and Max environments that have today become a fixture in the digital atelier of many composers.[39] But it was the assemblage of earlier text-based programs that was key to Saariaho's development of a compositional method in works like *IO* and *Nymphéa*, and to her creation of the 'transkaija' subroutine that crystallised this method. The disappearance of these programs derails any attempt at a complete reconstruction of the musical facts because all that remains are dispersed fragments of CHANT-FORMES code on sprocket-fed printer paper at the Sacher archives. For researchers, this code may provide a static view into Saariaho's compositional methods, but it was intended to be read by machines in the process of synthesizing and controlling sound. This dynamic, performative aspect of the code has been lost, transforming once-active digital representations into purely symbolic artifacts. The result is a partial record of Saariaho's creative process; and while it is certainly true that no archive is ever complete, and that problems of preservation also afflict collections of 'old' media in traditional archives, there is a particular mode of obsolescence that seems to be unique to new media artifacts. According to media theorist Wendy Hui Kyong Chun, this is because software is 'fundamentally ephemeral', making it difficult to study because 'most 'archived' programs can no longer be executed, and thus experienced, since the operating

systems and machines, with which they merge when running, have disappeared. Although these systems can be emulated, what is experienced is a reconstruction'.[40] Needless to say, the problem of a representational gap between older computer programs and their reconstruction in newer software weighs heavily on the question of digital music preservation, especially in the context of high art aesthetics, where the authenticity of an author's inscriptions and intentions is paramount.

As director of IRCAM in the early-2000s, Bernard Stiegler recognised that digitization opens a 'profound breach in the technology of memory', arguing that 'music, and particularly contemporary music, raises acute and essential questions about the temporal object in the digital era'.[41] The characterization of music here as a 'temporal object' can be traced back to Edmund Husserl's analogy of time consciousness to the perception of melody, which he apprehended as a continuous flow through the extension of impressions (*retention*) and anticipations (*protention*) into the present sensation of tone.[42] It also parallels Stiegler's own formulation of cinema as a 'temporal object' and his hypothesis of 'an *essentially* cinematographic structure for consciousness in general', in which montage-like principles of selection and the micro-temporal flux of twenty-four frames per second are linked to a broader 'problematic of tertiary memory' and phenomenological analysis of the perceived continuity of experience across a series of disparate instants.[43] Bridging the audio-visual domains, he posited that 'a film, like a melody is essentially a flux: it consists of its unity in and as flow. The temporal object, as flux, coincides with the stream of consciousness of which it is the object: the spectator's'.[44] In this way, subjects and objects, humans and their instrumental support systems – the 'whos' and the 'whats', as Stiegler had it – merge and co-constitute one another. While this sweeping hypothesis undergoes extensive development in the third volume of *Technics and Time*, the most interesting questions for the present study are how it might have informed Stiegler's practical work at the helm of IRCAM, and how it might shed light on digital technics underpinning the center's production, performance, and preservation of new musical works.

As mentioned earlier, Stiegler's stint as IRCAM director was marked by strong support for the development of a 'digital sound archive' that included the Multimedia Library for recording production activities, the Hypermedia Studio for presenting 'signed listenings' by expert music researchers, and the Semantic HiFi project for indexing and interacting with audio content via descriptive metadata. In addition, researchers there launched the in-house Sydney server to maintain 'technical information necessary to play the pieces composed at IRCAM'.[45] Due to the frequency of required software and system updates, this ongoing project entails re-porting musical algorithms into a new technical environment every few years, even though doing so raises difficult questions about how to safeguard the

authenticity of performance materials that change their mediatic form many times over. It is for this reason that IRCAM has actively prioritised the development of novel strategies for the safe migration and emulation of digital data across media systems.[46] There have also been efforts outside of IRCAM to develop international standards that ensure the *accuracy*, *readability*, and *intelligibility* of digital music documentation.[47] But even the widespread adoption of such standards can't fully guarantee the authenticity of performance-based media, as doing so relies on situated knowledge involved in multimodal tasks like running interactive software, balancing audio levels, or controlling spatial diffusion in live concert settings. These real-time practices fall outside the bounds of traditional archives, quietly cropping up around new technologies and getting conveyed on a person-to-person basis. Although some recent studies have sought to address this missing element by documenting the cultural techniques implicit in navigating hardware-software assemblages,[48] a total reconstruction of the musical fact remains elusive as ever; and this is true even in the case of pieces commissioned by IRCAM, which undoubtedly benefit from their status as pre-ordained masterworks worthy of preservation without submitting to the tests of scarcity and value that typically determine admissibility for artifacts in the archive.

The mandate behind the Sydney server has been serviced and streamlined by the fact that, since the early nineties, most visiting composers at IRCAM, including Saariaho, have utilised Max 'patches' when integrating acoustic instruments with live-electronic systems. Prior to this virtual technology, however, it was necessary to use an assortment of external devices, such as one finds in the following inventory of equipment used in original performances of *IO*:[49]

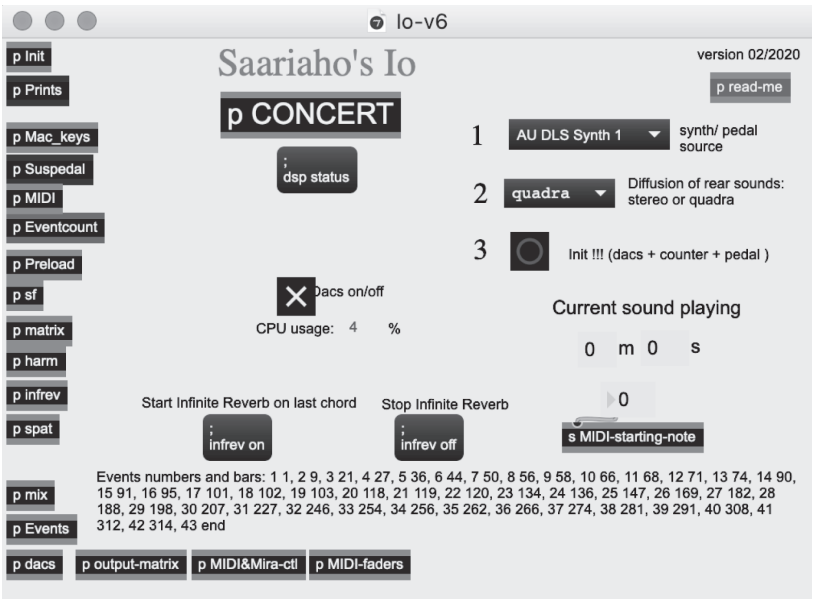
Audio Effects Processing	Mixing and MIDI Controls
Analog Publison (delay, harmonizer)	Yamaha DX7 synthesizer
Digital devices:	Macintosh computer
- Lexicon PCM-70 (delay, reverb)	Microphones, mixer, loudspeakers
- Yamaha SPX90 (delay, reverb, harmonizer)	
- Yamaha REV7 (reverb)	

No fewer than four devices were employed for sound processing, including one analogue machine (Publison) and three that were digital with MIDI capabilities (Lexicon PCM-70, Yamaha SPX90 and REV7). Additionally, an early Macintosh Plus computer piloted the devices, and a Yamaha DX7 synthesizer was used to trigger pre-recorded sound files.[50] A similar setup supported original performances of *Nymphéa*, with only a few differences; namely, Saariaho got rid of the analogue machine, traded some of the external MIDI processors for a Yamaha DMP7 digital mixer, and introduced the option of using contact microphones. Otherwise, the

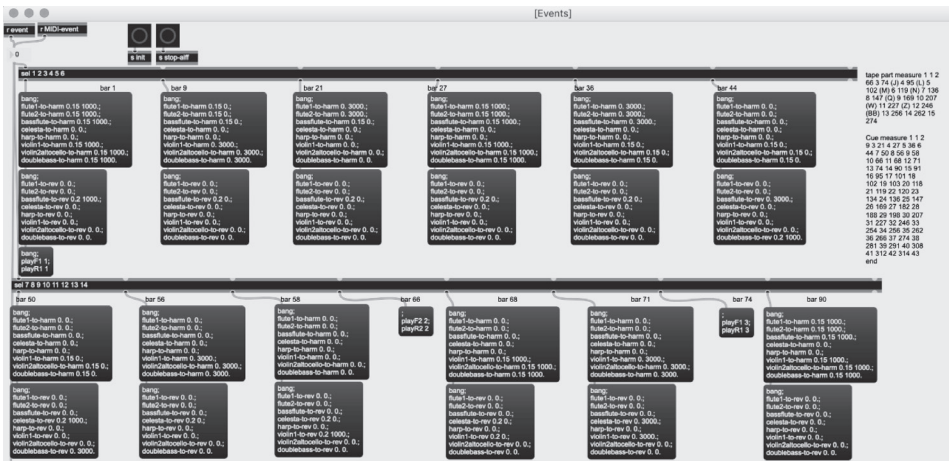
function of live electronics in both works is the same, with audio processing limited to a handful of basic techniques, including reverb, delay, and harmonization. In performances, these techniques were distributed across the whole network of devices, with each unit programmed to progress through its own series of audio configurations. Rather than leading to redundancy, the ad-hoc arrangement allowed Saariaho to exploit the functional overlap between devices, creating a characteristic staggering of musical processes as they gradually change states, one after the other in a perpetual relay.

FIGURES 12A–12B. Saariaho, *IO* software: (A) Max performance patch and (B) Event cue list.

A



B



A few years after *IO* premiered, the expansive list of machines itemised above would be encapsulated inside a single interface. Gone are the analog Publison, the array of external hardware for processing sound effects. Instead, a revised technical note calls for a Macintosh computer running Max software, which collects each of the programs from the previous devices and runs them through the performance patch in FIGURE 12A.[51] Within this main patch, additional 'subpatchers' are vertically arrayed along the left side, appearing as objects scripted with the letter 'p' as a prefix. One of these objects, titled 'p Events', is especially important, as it contains a cue list of audio effects, indicating how they correspond to measure numbers in the score. A portion of the list depicting Events 1–14 (mm. 1–90) is pictured in FIGURE 12B.

Looking closely, FIGURE 12B is remarkably clean, with neatly arranged modules connected by tidy cables. As with nearly all Max patches for Saariaho's works – many of which are maintained by her long-time partner and collaborator, Jean-Baptiste Barrière – the programming seems designed to be legible even to non-experts. This accommodation increases the accessibility of these technical documents to musicologists, theorists, and performers who might not have an extensive background in computing languages. Several key bits of information are quickly evident from a cursory analysis of the patch, including which effects are being applied to each instrument in any given bar, their relative degrees, and how long it takes for an effect to set in. Like the CHANT-FORMES system before it, musical processes in the Max event list are defined using a series of breakpoint functions, or value-time pairs, where the value indicates the amount of effect applied and the time in milliseconds (1000ms = 1s) indicates how long it takes to reach this value. So, for instance, in the first event at m. 1, a small touch of harmonization (0.15 on a scale of 0 to 1) is applied with a one-second onset duration to all instruments except celesta and harp, while reverb is applied to only bass flute (e.g., 'bassflute-to-rev 0.2 1000'). It is possible to open additional sub-patches to learn further information, such as exactly what kind of harmonization has been applied. In this case, the contents of the 'p harm' subpatch shown in FIGURE 12A reveal that, when engaged, the harmonizer consistently adds 50 cents and subtracts 45 cents from the input signal, producing a blurred center around the instrument's performed pitch. The effect is more of a tonal smearing than an actual harmony per se, and its use yields textural and timbral transformations rather than clear chordal structures. The other real-time processing techniques are similarly subtle, providing hints of delay, reverb, and filtering to the otherwise unprocessed sounds of the instruments. In total, these minimal effects add a veneer of artificial ambiance that allows the instruments on stage to better blend with the spatial diffusion of sounds through loudspeakers in the concert hall.

The archival record for *IO* and *Nymphéa* demonstrates how both works are rooted in a technocultural moment just prior to the arrival of patch-based interfaces, and how they have since been retrofitted to accommodate the rising prevalence of patching in performances of musical works using live-electronic components. In this sense, these pieces don't just illuminate Saariaho's development of a compositional method, they provide a prism for viewing the historical remediation of text-based commands in visual programming languages, as well as for apprehending the emergence, stabilization, and closure of a technical system built around the logic of patching as an operational metaphor. Having expanded to include processing for audio signals (MSP, 1998) and video (Jitter, 2003), Max now functions as a general-purpose tool in the 21st-century digital atelier; and yet, in keeping with its cultural genesis at IRCAM, the software continues to be associated with high art aesthetics in academic contexts, with marketing rhetoric placing a premium on authorial agency and characterising the program as a 'playground for invention… an infinitely flexible space'.[52] Perhaps nowhere is this message conveyed more effectively than the iconic blank page one sees upon opening Max. But as the program's inventor Miller Puckette has noted, 'even this blank page carries stylistic and cultural freight'.[53] Indeed, the interface assumes users should build instruments and audio effects from scratch, connecting scripted objects with cords to create algorithms that control the flow of sound, vision, and information through elaborate signal-processing chains. An interactive network thus produced folds together text-based commands with a visual patching metaphor that can be traced to analog modular synthesizers in the sixties, as well as to telephonic and telegraphic systems of a previous era, suggesting a functional elision of old and new media that deserves to be examined in further detail.

The repackaging of programming protocols in the guise of analog equipment fits into what media scholars have identified as a broader skeuomorphic tendency in software design,[54] whereby virtual 'folders' are used to organise files and icons of 'windows' provide access to different program interfaces, helping users navigate the otherwise-opaque tasks required to run a computer's operating system. Max's particular brand of skeuomorphism situates it within a longer history of sound synthesis and composition-as-research at places like IRCAM, distinguishing it from digital audio workstations (DAWs), such as Pro Tools or Logic Pro, which adopt the multi-track recording studio as their foundational metaphor. These divergent approaches to interface design have long represented rival paradigms of music-making, simulating the classical versus popular divide, with each side signaling closure around a particular set of social, aesthetic, and historical values encoded in software affordances. But more recently, the release of applications like Max for Live (2009) has complicated this picture by bundling Max's patching

capabilities together with Ableton Live, a DAW that is popular among producers of electronic dance music (EDM). The recombination of these programs in a modular framework brings together diverse models of composition and improvisation, while also joining software users and makers from distant cultural spheres. One imagines the procedural logic of Saariaho's compositional method, having been meticulously programmed in CHANT-FORMES and translated through Max, now co-mingling with audio loops, MIDI sequences, and a near-infinite world of virtual 'plug-in' devices inside the 'metamedium' of Max for Live.[55] Given this apparent re-opening of previously closed technical systems, what might music researchers learn by analysing the cultural histories embedded in such hybrid interfaces and studying their articulation to different aesthetic orientations? Conversely, what might software developers learn by examining the articulation of specific musical styles to different technological systems?

While questions of this magnitude lie beyond the immediate purview of this essay, my narrower focus on Saariaho's *IO* and *Nymphéa* has at least suggested the presence of a bi-directional feedback loop between composers and their surrounding media infrastructures. First, the composer's engagement with a dictionary of speech phonemes in CHANT facilitated her experiments with harmony and timbre in *Vers le blanc*. As explained, this same process is maintained in her later works, even as the underlying technologies shifted to facilitate custom analysis of instrumental models with the IANA program using the Terhardt algorithm. Second, Saariaho's encounter with linear breakpoint functions in CHANT led to further experimentation with evolutionary curves applied not only to pitch and rhythm, but to a variety of sub-note parameters (e.g., vibrato, tremolo, filters). This standard approach for scheduling time-based processes in CHANT informed her development of a compositional method with 'transkaija', and by the end of the decade, the whole interpolative framework would be remediated by visual programming environments as part of a closed technical system built around patching metaphors. Thus, while the support system that gave rise to 'transkaija' was soon eclipsed, the techniques encoded in the program would outlast the tool itself, leaving residual traces on future software development at IRCAM. Through the reciprocal interaction of composer and computer – companied with outside cycles through social relations at IRCAM – a techno-musical system slowly concretised in the form of tertiary extensions, many of which are now enshrined as commercial software on the IRCAM Forum. These hypomnesic supplements store coordinates of the musical system, while at the same time setting a horizon of possibility for what can be accessed through digital technics within that same system. Interdependent processes of exteriorization and interiorization prove critical at this point, as Stiegler reminds us by noting that, outside of instrumentality, there is 'no mind, no recall,

no memory of a past that one has not personally lived, no culture'.[56] Ultimately, it is only by excavating the different layers of media infrastructure associated with Saariaho's early computer-based music that it becomes possible to historicise this condition and contextualise the origins of tools and techniques that remain central to her compositional aesthetic. With this in mind, the present article has endeavored to show how an awareness of the technics behind *IO* and *Nymphéa* can inform analytic interpretations, not just of the composer's other works from this early period, but of recent works like *Saarkoski Songs*, providing important clues as to what lies beneath the oft-remarked upon 'atmospheres' and 'landscapes' of her imaginative sound palette. For if Saariaho can make 'even the most dissonant textures and soundscapes seem no less natural than an improbably gnarled tree', then it is in part because she has arrived at these naturalised phenomena through sustained engagement over the last four decades with a highly technologised environment at IRCAM, and it is this kind of engagement that must be revisited if we want to better understand the hybrid flux of material and temporal objects that constitute her music today.

Notes

1 *Saarikoski Songs* premiered at Boston Symphony Hall on February 24, 2021; it was preceded by an earlier setting of the song cycle for voice and piano (2013–2020), which Komsi recorded with Pia Varri on their 2021 album, *Sumun Läpi*, released by Coloramaestro Music. European performances of the orchestral version are scheduled to take place in 2023–2024 in Helsinki, Paris, Copenhagen, and London.

2 A.Z. Madonna, 'Thoughts of Ukraine Add Emotional Heft to BSO's Russian and Baltic Program', *Boston Globe*, 25 February 2022.

3 Mark Swed, 'Review: Celebrated Finnish Composer Kaija Saariaho Drove from L.A. to San Diego. 'Vista' was the Result', *Los Angeles Times*, 4 November 2021.

4 Anthony Tommasini, 'Review: A Newly Relevant '*L'Amour de Loin*' at the Met', *New York Times*, 2 December 2016. The premiere made headlines as the first opera composed by a woman to be presented by the Met in over a hundred years; the only other opera by a woman was Ethel Smith's *Der Wald*, performed in 1903.

5 See Ivanka Stoianova, 'Une œuvre de synthèse: analyse d'*Amers*', *Cahiers de l'Ircam*, 6, 1994, pp. 43–66; Risto Nieminen (ed.), 'Kaija Saariaho', *Cahiers de l'Ircam*: *Compositeurs d'aujourd'hui*, 6, 1994. See also Saariaho's early publications in Finnish: Kaija Saariaho, 'Matkalta. Freiburgissa…', *Uuden Ajan Aura*, 3–4, 1981, pp. 22–23; Kaija Saariaho, 'Kirkuu saat, mutta lennä!', in *Ammatti: säveltäjä : yhdentoista suomalaisen säveltäjän puheenvuoro aikamme musiikista*, ed. by Pekka Hako and Risto Nieminen, Helskinki: Synkooppi ry, 1981, pp. 115–119; Kaija Saariaho, 'Säveltäjä! (Compositeur!)', *Synkooppi*, 17/2, 1984, pp. 28–29.

6 See James Donaldson, 'Melody on the Threshold in Spectral Music', *Music Theory Online*, 27/2, 2021, doi:10.30535/mto.27.2.9; Alison Wahl, *Timbral Intention: Examining the Contemporary Performance Practice Techniques of Kaija Saariaho's Vocal Music*, PhD diss., Northwestern University, 2017; Eric Drott, 'Saariaho, Timbre, and Tonality', in *Tonality Since 1950*, ed. by Felix Wörner, Ullrich Scheideler, and Philip Rupprecht, Wiesbaden: Franz Steiner Verlag, pp. 259–281; Judith Lochhead, *Reconceiving Structure in Contemporary Music: New Tools in Music Theory in Analysis*, Abingdon: Routledge, 2016, pp. 105–122 ('Technê of Radiance: Kaija Saariaho's *Lonh*'); John Roeder, 'Art and Digital Records: Paradoxes and Problems of Preservation', *Archivaria*, 65/1, 2008, pp. 151–163; Karen J. Siegel, *Timbral Transformations in Kaija Saariaho's* From the Grammar of My Dreams, PhD diss., City University of New York, 2014; *Kaija Saariaho: Visions, Narratives, Dialogues*, ed. by Tim Howell with Jon Hargreaves and Michael Rofe, Farnham: Ashgate, 2011; Clifton Callender, 'Continuous Transformations', *Music Theory Online*, 10/3, 2004; Anne Sivuoja-Gunaratnam, 'Desire and Distance in Kaija Saariaho's *Lonh*', *Organised Sound*, 8/1, 2003, pp. 71–84; Taina Riikonen, *Jälkiä itsessä : narratiivisia huilisti-identiteettejä Kaija Saariahon säveltämässä musiikissa*, Turun yliopisto [University of Turku], 2005; 'The Works of Kaija Saariaho, Philip Hurel, and Marc-André Dalbevie—*stile concertato, stile concitato, stile rappresentativo*', ed. by Damien Poussett, Joshua Fineberg, and Ronan Hyacinthe, *Contemporary Music Review*, 19/3, 2000, pp. 67–110; Vesa KanKaanpää, 'Displaced Time: Transcontextual References to Time in Kaija Saariaho's *Stilleben*', *Organised Sound*, 1/2, 1996, pp. 87–92.

7 Landon Morrison, 'Encoding Post-Spectral Sound: Kaija Saariaho's Early Electronic Music at IRCAM, 1982–1987', *Music Theory Online*, 27/3, 2021, https://mtosmt.org/issues/mto.21.27.3/mto.21.27.3.morrison.html. See also 'Reassembling Kaija Saariaho's *Vers le blanc* (1982)', *Mitteilungen der Paul Sacher Stiftung*, 33, 2020, pp. 37–44.

8 My research at IRCAM in Paris took place during Summer 2017 and at the Paul Sacher Foundation in Basel during Summer/ Fall 2018. I want to thank both institutions for providing access to resources, and in particular, I want to thank Heidy Zimmermann, who curates the Saariaho collection at the Paul Sacher Foundation, for facilitating the reproduction of facsimiles in the present article.

9 Stiegler describes this process as one of 'exteriorization, in which nothing is any longer immediately at hand, where everything is found mediated and instrumentalized'. See *Technics and Time*, translated by Richard Beardsworth and George Collins, Stanford: Stanford University Press, 1998, pp. 133. Beyond Stiegler, my use of 'technics' draws on writings by a range of philosophers of technology, including Lewis Mumford, *Technics and Civilization*, New York: Harcourt Brace and Company, 1934; Gilbert Simondon, 'Culture and technics (1965)', *Radical Philosophy*, 189, January/February 2015, pp. 17–23.

10 Stiegler, Michael Fingerhut, Nicolas Donin, 'The IRCAM Digital Sound Archive in Context', *DigiCULT*, 6, 2003, pp. 19–22.

11 Originally published in Finnish, this text appears in French translation in a collected volume of Saariaho's publications, *Le Passage Des Frontières: Écrits Sur La Musique*, ed. by Stéphane Roth, Paris: Éditions MF, 2013, p. 19.

12 *Le Passage Des Frontières*, p. 22.

13 Reflecting on the exposure to new musical trends that accompanied her international travels, Saariaho recently remarked: 'There was not much that we heard in performance, but of course there were influences from Ligeti, who I loved, from Nono, some of whose music I liked a lot, and from Messiaen, whose work Paavo made me analyse. And Berio, too. The library was

very good at the Sibelius Academy, but it wasn't really before I went to Darmstadt in 1978 that I heard new music in performance'; for more, see 'Meet the Composer: Kaija Saariaho in Conversation with Tom Service', in Howell, *Kaija Saariaho*, pp. 3–14.

14 Howell, *Kaija Saariaho*, p. 9.

15 Howell, *Kaija Saariaho*, p. 8.

16 Xavier Rodet, Yves Potart, and Jean-Baptiste Barrière, 'The CHANT Project: From the Synthesis of the Singing Voice to Synthesis in General', *Computer Music Journal*, 8/3, 1984, pp. 15–31.

17 See Stephen McAdams and Kaija Saariaho, 'Qualities and Functions of Musical Timbre', *Proceedings of the International Computer Music Conference*, 1985, pp. 367–374; Jan Vandenheede and Kaija Saariaho, 'Éléments d'analyse technique de *IO*', *Cahier d'analyse création et technologie*, Paris: IRCAM, 1988; *Le Timbre: métaphore pour la composition*, ed. by Jean-Baptiste Barrière, Paris: C. Bourgois, 1991.

18 In programming parlance, 'breakpoint functions' are coordinates used to plot the trajectory of a line that indicates change over time; as such, their use to define all sound-based processes in CHANT imbued the program with a strong sense of linearity.

19 This form diagram of *Vers le blanc* is dated July 19, 1982. A note on the margins (not pictured in **FIGURE 1**) reads: 'This piece was realized at IRCAM, Paris, during the spring 1982 (programme 'chant'), with a technical help of Jean-Baptiste Barrière, whom I thank for the innumerable advices. The original version is on 4 traces'.

20 Kaija Saariaho, 'Shaping a Compositional Network with Computers', *Proceedings of the International Computer Music Conference*, 1984, pp. 163–165: 163.

21 The 'transkaija' program is explicated in an internal IRCAM document on the creation of *IO*; see Vanenheede and Saariaho, 'Éléments d'analyse technique de *IO*'.

22 Kaija Saariaho, 'Using the Computer in a Search for New Aspects of Timbre Organisation and Composition', *Proceedings of the International Computer Music Conference*, 1983, pp. 269–273; Saariaho, 'Shaping a Compositional Network with Computers'.

23 See Vanenheede and Saariaho, 'Éléments d'analyse technique de *IO*', p. 5.

24 Saariaho, *Lichtbogen* (1986), program note, https://saariaho.org/works/lichtbogen/.

25 See Wataru Miyakawa, 'The Role of the Drawings in Kaija Saariaho's *Lichtbogen*', *Journal of the Musicological Society of Japan*, 66/1, 2020, pp. 51–68; James O'Callaghan and Arne Eigenfeldt, 'Gesture Transformation Through Electronics in the Music of Kaija Saariaho', *Proceedings of the Seventh Electroacoustic Music Studies Network Conference*, 2010, http://www.ems-network.org/IMG/pdf_EMS10_OCallaghan_Eigenfeldt.pdf; Anne Sivuoja-Gunaratnam, 'Miniatures and Tensions: Phenomenological Reverberations in and around Kaija Saariaho's *Lichtbogen* (1985–1986)', *Intersections*, 25/1–2, 2005, pp. 44–66; Vesa KanKaanpää, 'Displaced Time: Transcontextual References to Time in Kaija Saariaho's *Stilleben*', *Organised Sound*, 1/2, 1996, pp. 87–92.

26 Morrison, 'Encoding Post-Spectral Sound'.

27 This program note for *Jardin secret I* is contained at Paul Sacher Foundation, Basel.

28 Saariaho, *Le Passage Des Frontières*, p. 130.

29 Ernst Terhardt, Gerhard Stoll, and Manfred Seewann, 'Algorithm for Extraction of Pitch and Pitch Salience from Complex Tone Signals', *Journal of the Acoustic Society of America*, 71/3, 1982, pp. 679–688.

30 See Todor Todoroff, Eric Daubresse, and Joshua Fineberg, 'IANA (A Real-Time Environment for Analysis and Extraction of Frequency Components of complex orchestral sounds and its

application within a musical realization)', *Proceedings of the International Computer Music Conference*, 1995, pp. 292–293 for real-time implementation of Terhardt's algorithm; see IRCAM Forum website for implementation of IANA as part of 'Max Sound Box', accessible here: https://forum.ircam.fr/projects/detail/max-sound-box/.

31 The 'scale of 0 to 1000' cited here might seem improbable given the low values included for relative amplitude and perceptual salience, but this measurement is confirmed by a technical description that appears on similar IANA analyses available at the Paul Sacher Foundation, one of which can be viewed as a facsimile reproduced in **FIGURE 10**.

32 **FIGURE 4** appears in Saariaho, 'Timbre et harmonie', in Barrière, *Le Timbre*, p. 123 (original edition: Kaija Saariaho, 'Timbre and Harmony: Interpolations of Timbral Structures', *Contemporary Music Review*, 2/1, 1987, pp. 93–133).

33 Saariaho, program note, https://saariaho.org/works/nymphea/.

34 A different spiral from the *Nymphéa* collection was recently reproduced in José L. Besada and Cristóbal Pagán Cánovas, 'Timelines in Spectral Composition: A Cognitive Approach to Musical Creativity', *Organised Sound*, 25/2, 2020, pp. 142–155: 149, but it lacks any indication of sound types, instead featuring the proportions of a spiral measured on graphing paper.

35 Gérard Grisey, 'Tempus ex Machina: A Composer's Reflection's on Musical Time', *Contemporary Music Review*, 2/1, 1987, pp. 239–275: 249. In Grisey's own music, one thinks of the second half of his work *Talea* (1986), which recursively spirals through the same material, even as it stretches to the point of straining a listener's ability to hold onto musical connections.

36 Grisey, 'Tempus ex Machina', p. 249.

37 Rofe, 'Capturing Time and Giving It Form: *Nymphéa*', in Howell, *Kaija Saariaho*, pp. 81–106.

38 Marc Battier and Gilbert Nouno, 'L'électronique dans l'opéra de Kaija Saariaho, *L'Amour de loin*', *Musurgia*, 10/2, 2003, pp. 51–59: 52.

39 See Mikael Laurson and Jacques Duthen, 'PatchWork, a graphical language in PreForm', *Proceedings of the International Computer Music Conference*, 1989, pp. 172–175; Miller Puckette, 'Max at Seventeen', *Computer Music Journal*, 26/4, 2002, pp. 31–43.

40 Wendy Hui Kyong Chun, *Programmed Visions: Software and Memory*, Cambridge, Mass.: MIT Press, 2011, p. 3, doi:10.7551/mitpress/9780262015424.001.0001.

41 Stiegler et al., 'The IRCAM Digital Sound Archive in Context', pp. 19 and 22.

42 Edmund Husserl, *On the Phenomenology of the Consciousness of Internal Time (1893–1917)*, translated by John Barnett Brough, Dordrecht: Kluwer, 1991 [1966], p. 11.

43 Stiegler, *Technics and Time, 3: Cinematic Time and the Question of Malaise*, translated by Stephen Barker, Stanford: Stanford University Press, 2011, p. 13.

44 Stiegler, *Technics and Time, 3*, p. 12.

45 The Sydney server was developed by Alain Bonardi, Serge Lemouton, and others as an institutional database for maintaining 'required equipment, technical diagrams, set-up instructions, and more'; visit https://brahms.ircam.fr/sidney/.

46 For an overview of preservation efforts by IRCAM researchers, see Alain Bonardi and Jérome Barthélemy, 'The Preservation, Emulation, Migration, and Virtualization of Live Electronics for Performing Arts: An Overview of Musical Issues', *Journal of Computing and Cultural Heritage*, 1/1, 2008, pp. 1–16; Serge Lemouton, Alain Bonardi, Laurent Pottier, and Jacques Warnier, 'On the Documentation of Electronic Music', *Computer Music Journal*, 42/4, 2018, pp. 41–58.

47 See, for instance, Brent Lee, 'Issues Surrounding the Preservation of Digital Music Documents', *Archivaria*, 50, 2006, pp. 193–204. John Roeder, 'Art and Digital Records: Paradoxes and

Problems of Preservation', *Archivaria*, 65/1, 2008, pp. 151–163. The latter author was involved in the InterPARES project (International Research on Permanent Authentic Records in Electronic Systems); see his excellent introductory resource to literature on digital music preservation, 'Authenticity, Accuracy, and Reliability of Artworks: Annotated Bibliography' (2004–2016), the latest version of which can be accessed online, http://www.interpares.org/display_file.cfm?doc=ip2_biblio_aar_focus_1.pdf.

48 On archiving the social transmission of digital music practices, see Guillaume Boutard and Catherine Guastavino, 'Archiving Electroacoustic and Mixed Music: Significant Knowledge Involved in the Creative Process of Works with Spatialisation', *Journal of Documentation*, 68/6, 2012, pp. 749–771; Guillaume. Boutard, 'Co-Construction of Meaning, Creative Processes and Digital Curation', *Journal of Documentation*, 72/4, 2016, pp. 755–780.

49 Vanenheede and Saariaho, 'Éléments d'analyse technique de *IO*'.

50 It is important to note these are only the machines required for real-time processing of live electronics during actual performances; additional production equipment was used as part of the compositional process, including the CHANT-FORMES system running on the VAX 780 computer with an FPS 100 array processor, the CRIME environment running the IANA analysis package, and the INA/GRM 123 studio spatialization programs.

51 The Max patch for *IO* shown in **FIGURES 12A AND 12B** is the 'latest version' (v.6) available for download through Saariaho's personal website: http://saariaho.org/IO-electronics.html. A note in the upper-right corner indicates the patch was revised in February 2020.

52 Cycling '74 website, https://cycling74.com/products/max.

53 Miller Puckette, 'Max at Seventeen', *Computer Music Journal*, 26/4, 2002, pp. 31–43: 39.

54 See, for instance, Katherine Hayles, *How We Became Posthuman: Virtual Bodies in Cybernetics, Literature, and Informatics*, Chicago: University of Chicago Press, 1999; Adam Bell, Ethan Hein, and Jarrod Ratcliffe, 'Beyond Skeuomorphism: The Evolution of Music Production Software User Interface Metaphors', *Journal on the Art of Record Production*, 9, 2015, https://www.arpjournal.com/asarpwp/beyond-skeuomorphism-the-evolution-of-music-production-software-user-interface-metaphors-2/.

55 The idea of computers as a 'metamedium' appears in Alan Kay, 'Computer Software', *Scientific American*, 251/3, 1984, pp. 52–59.

56 Stiegler, *Technics and Time, 3*, p. 39.