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What are the Three Paradigms of Retirement Income Planning?

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ABSTRACT: There exists a semi-hidden and little researched connection between planning and software programming that supports that planning, as well as little research into the connection to planning and programming related to the paradigm that exists underlying those connections. This paper discusses the paradigms of retirement income planning from past, to present, and observations to advance the planning profession and research into the future. The profession, researchers, and software programmers have transitioned from the first to the second paradigm and has yet to visualize the third paradigm to make that paradigm shift. Retirees continue to age year by year, but each cohort has a different distribution period due to the ever-decreasing time remaining in longevity tables *as they age*. There is *not* a universal retiree (as implied by current research using a single distribution time period with a single allocation; or at best two or three time periods and allocations). Instead, there exist many retirees with many different allocations and many remaining distributions time periods. Thus, one rule of thumb approach e.g., the 4% rule (or any drawdown rate) with inflation applied thereafter, or one Monte Carlo simulation, can't apply to all allocations plus all time periods at the same time because of those different ages with correlating shorter or longer remaining longevity for income drawdown. Therefore, research to date has been narrowly focused, which unintentionally leads to a narrowly applied approach for practitioners as well. Frank 2022a introduced *how to model* retiree drawdowns through a method that applies to any retiree at any age and subsequently over each retiree's remaining lifetime by cohort ages.

Therefore, researchers need to evaluate all the different time frames as well as many different efficient allocations, optimized along an efficient frontier range (Statman, Clark, 2013) to derive conclusions that can apply to any retiree at any age, not just an early-stage retiree (long term drawdown periods), i.e., a narrow set of early-stage cohorts while ignoring a large majority of others in many later stages of retirement (shorter term drawdown periods). The current paradigm ignores research and modeling later-stage retiree spending as well as the transition from any earlier stage into any later stage while aging. The author is a practitioner nearing nearly three decades specializing in research and application of drawdown of portfolios for supplemental retirement income, clinically with many different retirees of many different ages all at the same moment in time. Time, the transition between time periods, and control variables are key elements coming from the author's physics background. The author also has numerous research papers published in the *Journal of Financial Planning* (Frank, et. al., 2011, 2012a, 2012b, 2016, and numerous other published papers leading to the thoughts in these referenced papers leading to thoughts below). The author suggests integrating many different disciplines is important to advancing retirement income planning into more focused modeling, rather than today's single simulation approach within a narrowly applied functional or career-based discipline approach.

KEYWORDS: Financial Markets, Probabilities, Statistical Methods, Financial Services, Personal Economics, Retirement Income, Longevity, Age Based Modeling, Fintech, Cross-Disciplinary Business Management, Multi-Disciplinary Organization Management, Interdisciplinary Organization Management, Organizational Management

JEL Classification: C1, C29, C39, C5, C6, G4, G29, G40, M10, M15, 033, Y80

INTRODUCTION

When you Google "retirement planning" you typically get results about 401ks or investing. On the search topic of retirement, you get *few results* on how to *plan* for, *transition* into, and/or prudently *sustain* income once retired from early-stage (long terms) to later-stage (shorter terms) retiree years as they age. The term "retirement" suggests, and Google finds results on, the savings and investing part. However, the use of the terms "retirement plan," or "retirement planning," don't actually have much to do with the planning part at all! Instead, those terms only relate to savings or investing, i.e., an accumulation bias. The "planning" part has to do with questions how much you need to save with little about how a retiree at any given age may spend it down to last the rest of their life. Nor does the "planning" part address a unified model approach that includes accumulation and modeled transition between accumulation and drawdown. What allocation does long term, or shorter term, distributions periods are suggested? At what age range does allocation change? At what age is retirement feasible in the first place? Why does methodology between accumulation years and drawdown years change with a "retirement red zone" attempting to explain that transition? These questions have little to do with investing alone, but more with how to save, and then use investment resources for overall goals in life, with retirement being the primary focus for most people and other goals as subsets of current lifestyle and retirement lifestyle.

In other words, the term retirement plan totally misses much of the issues. The true application of the term retirement plan, meaning the planning part, has gone through phases historically. I'll call them paradigms, since they have to do with how the planning is *visualized and computed,* for the purposes of this paper.

Merriam-Webster's paradigm definition: "a philosophical and theoretical framework of a scientific school or discipline **within which theories, laws, and generalizations and the experiments performed in support of them** are formulated." The author's bold emphasis highlights the focus of the discussion below.

The profession is currently trending from a sales focus to a planning focus, but not yet well supported by software or by research by researchers since research and software programming is operating in the second of the three paradigms as discussed below.

We are presently operating in the 2nd paradigm, built upon the 1st paradigm, for retirement planning computations. I'm suggesting there's a 3rd paradigm, improving upon its' predecessors, yet to come. However, should paradigms develop into dogmas, or at least rules of thumb, then resistance sets in, and advancements never come, or they come very slowly.
Below are the observations from a researcher, practitioner, advisor, and planner on the frontline, since 1994, nearing 30 years observing. researching, publishing, applying, and advising real people, and living through the paradigms described below. Little literature exists exploring the concepts explored and proposed in this paper and thus literature relating specifically to the concepts in this paper are referenced throughout where a concept applies. Methodology and data are found in the referenced paper for concepts too. This paper proposes the "why" for the need to modernize retirement income planning, while Frank 2022a hypothesizes the "how." The challenge? The hypothesis' found in both papers should be further studied, and outcomes promulgated widely in all aspects of the profession as argued below so new insights may be applied quickly.

Upfront: What's different?

The fundamental paradigm shift into the 3rd paradigm is through how longevity is viewed and applied to the process of aging over time, because longevity is not static with age, and aging itself is not static either. They're both dynamic and this is not captured in today's static paradigm used by both researchers and software programmers (and advisers using research and software are also thus limited). A dynamic longevity application has a profound effect on cash flows and balances by age. The author will illustrate this below.

The 3rd paradigm does 2 things … 1) Allows more visibility on cash flows, balances *and allocation* by age, and 2) provides clearer calculated decision points for spending adjustments scaled both by age *and allocation*. The use of longevity, and a strategic use of longevity percentiles, provides **THE ONE small thing that shifts the paradigm and allows for 1) more precise calculations *by age*, 2) when to make spending adjustments, and by what magnitude, *by age*, 3) what optimized/efficient allocation to optimize supplemental retirement income *by age*, and 4) finally provides insight into remaining balances for surviving spouse and heirs *by age*.** "By age" here means at any age regardless of attained age, from the present into the future to then end of the life tables used (ideally those that go to age 120 for health cohorts; or Social Security tables representing the general population which includes less healthy cohorts). Table selection is important because the derived time-period directly influences drawdown rates (shorter periods result in higher drawdown rates; longer periods lower).

The transition between the present 2nd paradigm, discussed below, into the 3rd paradigm is to expand the "box" so "outside the box" moves inside. A Chinese proverb states: "One's Mind, once stretched by a new idea, never regains its original dimensions." This movement and stretching are accomplished by utilizing the stochastic process, i.e., Monte Carlo, more thoroughly in modeling rather than one simulation at a time. What does that mean?
Working years are not one single time-period followed by another single time-period in retirement. Both phases for people are part of a continuous rolling series of time periods that seamlessly transition from savings to spending at a chosen retirement age. Retirees retire at different ages. Retirees ages are different from other retirees as they age as well since not all retirees are part

of the same cohort. All people age through time year by year, but today's simulations do not account for this slow transition of time periods or *between* time periods. The concepts of time, rolling or sequential time periods, and control variables come from the author's early background in physics.

All retirees do not have the same "default" 30 year time period common in research. Nor do all retirees have the same "default" allocation characteristics. What of other time periods? Of other allocations? How are those time periods and allocations assigned appropriately to each retiree? How are those time period and allocation assignments adjusted as each retiree ages and transitions between time periods?

The future markets and economy don't change based on *when* each person retires; no, markets and the economy continue to flow over time too. That is also life, with many phases and transitions over time. The same economic and market events happen *at different ages* for different people because everyone is a different age at the same time (unless you have identical birth years as cohorts). People also retire *at different ages.* People understand aging and the author's clinical experience also shows they understand rolling longevity (illustrated below); in fact, they are more comfortable with their plan once they see that longevity bow wave (discussed below) is incorporated.

The present, 2nd paradigm, has a static view where simulations are run over single periods, with single allocations, and where periods and/or allocation are changed one at a time in a new simulation. Research is dominated by this view of single simulations more often with a limited selection of inefficient allocations. Other time periods or allocations are not explored. The problem with the present paradigm is there are no smooth transitions as one ages, nor is there a transition between working and retirement years using the same process to model *when* that transition may be feasible (at what age do all the sources of income combine to sustain the desired lifestyle standard of living?). That feasibility today is by doing single period simulations at different ages to "find" that feasible transition age. The process today does not recognize how differing time periods and/or savings rate changes influence the target accumulation value.

Modeling should reflect life as a continuum with phases and transitions; yet built upon a single unified and cohesive modeling program that applies to everyone regardless of their age. In other words, each person working or retired simply "moves" through a unified model that models aging and optimum allocations by age as well. The point of retirement is simply a transition from contributing to withdrawing; a point when the sum of the income sources totals the sum of the desired target lifestyle expenses. Retirement transition planning then becomes determining when that transition point may occur, or what meaningful adjustments change that target retirement age outcome to a more desirable, or a more realistic, age.
There are many different allocations below an efficient allocation frontier with the same stock/bond percentages. They may appear to be the same allocation, e.g., 60/40, but the problem is "efficient" of which only a few may fall within an efficient *range* (Statman, Clark. 2013, Figure 1). The Target Band graph, illustrated in Appendix 1, shows an efficient range connecting the grey dots where each dot represents an allocation comprised of Asset Classes selected with the corresponding Historical Return Index data. Any allocation combination of asset classes, with corresponding returns and standard deviations, that fall below the efficient range do *not* produce efficient drawdown rates when the Iteration Failure Rate is applied as a control variable to compare data over various allocations and/or time-periods as discussed below. It is an error to assume the characteristics of an efficient allocation and apply those characteristics to a similar allocation that does not fall within the efficient range. This leads to higher drawdown results that would apply to the efficient characteristics but leads to faster depletion because the portfolio is not efficiently designed to support those higher drawdowns. In other words, actual portfolio characteristics should be used, unless those characteristics apply to target portfolios in actual use. This is due to volatility drag simply stated as "what returns give volatility take away."

The issue is that few allocations are optimized to be efficient allocations; and worse all those holding such allocations *assume* the allocations are efficient, when they are not. Optimized and efficient allocations lead to the money invested as such working as hard as it can to in turn provide *optimized* prudent and sustainable supplemental income on a total return basis from the portfolio for retirement.

Below is a description of where we came from in terms of retirement planning, where we are in terms of paradigm, and how to evolve and improve insights from financial planning software programming. Figure 9 illustrates a real retiree example where methodology in this paper and Frank 2022a has been applied, with small adjustments as new research evidence came available (see references).

Paradigm shifts are often subtle changes in points of view and thinking. This rolling time periods shift in thinking will be explained below, along with the three major paradigms and how software programming, has been, and may continue to be improved. Application of new statistical and mathematical concepts are also discussed. Only by stepping outside of a simulation mindset to get a more three-dimensional perspective on retirement planning can deeper insights come, much like the Gaia mission is doing mapping the Milky Way in 3D. Modeling the *data cloud from hundreds of separate simulations,* to step outside of any one simulation, provides the much-needed 3D view for retirement planning (Frank, et. al., 2012a).

What are the three paradigms?

The First Paradigm – The Past

The **first paradigm** was deterministic in nature. The author recalls, as many older planners do during their study period to become a Certified Financial Planner Practitioner™, that retirement planning was done via the HP-12C handheld calculator. One would calculate a rate of return over a given time period to determine how much need to be saved for retirement. The calculator also would do a spend down over a set time period where all the money may be spent by the end of that time frame. It was a deterministic approach using averages, which is a flawed approach (Savage, et al., 2012).

William Bengen's seminal paper (Bengen, 1994) began the transition from the deterministic paradigm in that it was an initial look at historical returns applied to retirement spend-down of invested money. His paper wasn't a stochastic application; it was a form of back-tested historical evaluation looking back on history to determine how long withdrawals may last, in number of years, by varying the withdrawal rate. This isn't the stochastic, or in layman's terms, Monte Carlo we know today. Unfortunately, Bengen's work developed into a heuristic, or mental shortcut, with other heuristics added to it, rather than to further develop through more thoughtful simulation applications. It's unfortunate because the nuances and significance of different time periods in his work were underappreciated at best and ignored at worst. Those time-period differences will become apparent below in the longevity "bow wave" discussion.

The issue with heuristics is that they force one by one computations and simulations because they're short cuts, rather than computing actual values for each and every age, longevity time frame, and allocation possibilities, as discussed below in the third paradigm. In other words, heuristic short cuts also lead to solution shortcuts – now what most people really desire when it comes to something as important as sustainable and prudent retirement income. Or worse, rules of thumbs get developed that have led in some cases to withdrawals unrelated to 1) allocation characteristics, 2) portfolio balances, and 3) age (time period over which withdrawals remain to occur).

However, Bengen's work brought about insights into the issues of the first paradigm, that resulted in debate, that led to the transition into what I call the **second paradigm** in which we are today. Advancement and progress between paradigms have been glacial as can be seen from the start of the 2nd paradigm with Bengen's work in 1994 (a while ago)! The many examples and applications of advances in other professions over the past two and half decades and more have not happened in the financial planning profession … because updated applications and computer and programming capabilities have not been incorporated into the planning profession. The focus of such advances have been applied through the lens of the second paradigm, without advancing into the third, as explained next.

The Second Paradigm – The Present

The **second paradigm** is *deterministic in nature with a Monte Carlo overlay*. It is a hybrid. It is still a "calculation" based approach since it is over a set period with a single set of factors inputted to simulate solely different market sequences, instead of a model-based approach the author describes below that incorporates many ignored but influential and important variables. There is a big difference between a simulation, and a model as will be expanded on below. The second paradigm in other words, is a simulation with heuristic, or shortcut, inputs for a hybrid method that doesn't yet model aging. It computes solutions one by one requiring other simulations to compute other possibilities for time spans and/or allocations – a "hunt and peck" methodology seeking answers one age, i.e., a single distribution time period at a time with one portfolio allocation at a time within that single time period. This single variable approach originates from the deterministic nature in the 1st paradigm.

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The fundamental problem with Monte Carlo over single time periods is the ever-growing uncertainty of possible outcomes in later years that loosely imply age, and reliance on what is known as probability of failure (POF) interpreted as plan failure, when POF really means iteration failure rate (IFR) of the simulation's iterations, whether there are 1,000 iterations, or 5,000 or any number of iterations cast within that single simulation. One simulation has many iterations within, and a single simulation in not a model, it's essentially a single calculation repeated multiple times over the same time-period with the same allocation.

Essentially, today's paradigm, or the second paradigm, is taking a given time-period along with a given set of portfolio statistical characteristics, or single factors at one time, and running a Monte Carlo process to derive a "probability of failure." What that probability of failure really means is the result of how many simulation *iterations fail.* Probability of failure (or success) is a misnomer today since it implies through common usage today the success or failure of the *overall plan*, thus implying that the retiree runs out of money, when in truth only the portfolio *might* run out of money. However, this probability of running out of money (or success of not running out of money) ignores the fact that Social Security, and pensions for those who have them, or properly structured immediate annuity incomes, do not run out. This approach also often results in trying to adjust, or modify, cash flows *within the simulation*, as opposed to *between simulations* (discussed below) in order to get "a better" result.

The academic point of view is also based on first or second paradigm views using single periods and allocations. It is rare today to read any research of multiple periods and allocations being studied, compared, and contrasted to represent changes over time (age). Such more diligent research would result in a three-dimensional view of portfolio distributions over time as seen in Figure 1. (Frank, et al., 2011, 2012a and Suarez, 2020, Figure 26). The reader may zoom in on any/all the figures to view detail better.

Note the transition in Figure 1's upper panels between the time-period labeling, from "Years Remaining" (left panel) to "Retiree Age" (right panel). This illustrates how long time periods are followed by ever shorter periods of time align and how this time-period nature aligns with age. In other words, the proper ordering of simulation time periods to align with age is for long-period time periods coming before shorter-periods so that age-based modeling is achieved. Figure 1's lower panel illustrates the fact that sequence risk exists at all ages and comparing lower risk allocations (<100% equity) dispersion of results manages that dispersion of outcomes better than higher risk allocations. If a retiree should seek a low Probability of Failure (POF) (author suggests the better term representing simulations is Iteration Failure Rate (IFR)), e.g., 10%, then what happens with that fixed dollar (F$) spending amount when market declines lead to lower portfolio balances, the IFR rises (drawdown rates rise) signaling at some that the retiree should take action to lower IFR, with the largest impact coming from reducing spending, a relationship consistent across time frames and allocations (Frank et. al, 2011, 2022b).

Viewing the upper panel in Figure 1, time (age), allocation, and drawdown rates (cash flow divided by portfolio balance) are connected to each other through iteration failure rates, with time (age) the biggest driver to drawdown rate differences as seen in the lower panel of Figure 1. Therefore, aging has the largest impact on drawdown rate changes when you directly associate time (distribution period) to age. Aging will be discussed in terms of longevity below. Also note in Figure 1 that iteration failure rate (IFR) is the control variable that makes age (time) comparisons an apples-to-apples comparison (Figures from Frank 2011, 2012a use the "old" term Probability of Failure (POF), a relic of 2nd paradigm nomenclature, prior to relabeling to IFR to better represent what that variable represents). Note too, that the longevity is held constant at the 50th percentile so that age comparisons are also apples-to-apples. Changing longevity percentiles strategically will be discussed below.

Thus, it becomes hard to ignore the evidence that allocation, age (time), and iteration failure rate (IFR) play a major role in drawdown rate determination. Historical rates (Appendix 1) or current market assumptions, assuming they are utilized in efficiently optimized allocations, both play a role in drawdown modeling, depending on the use of such data sets. This paper uses historical data represented in Appendix 1.

What are the Three Paradigms of Retirement Income Planning?

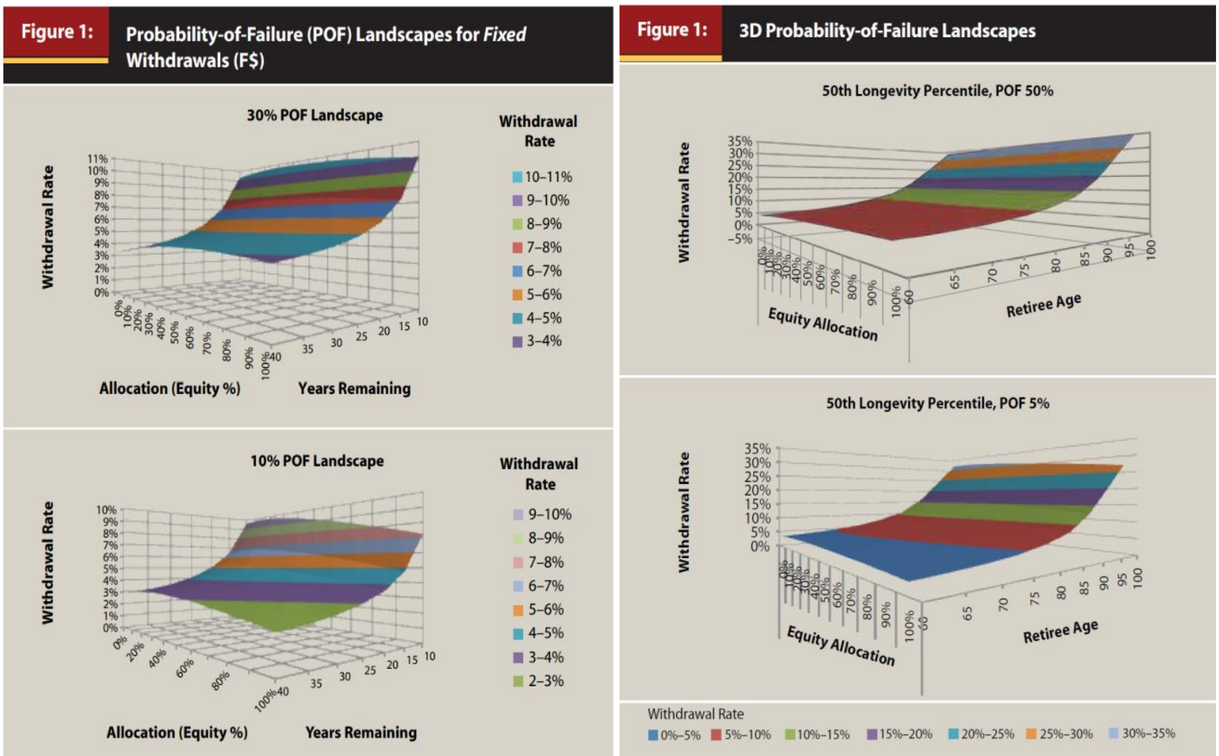

Figure 1. Upper panel (of *this* paper's Figure 1)

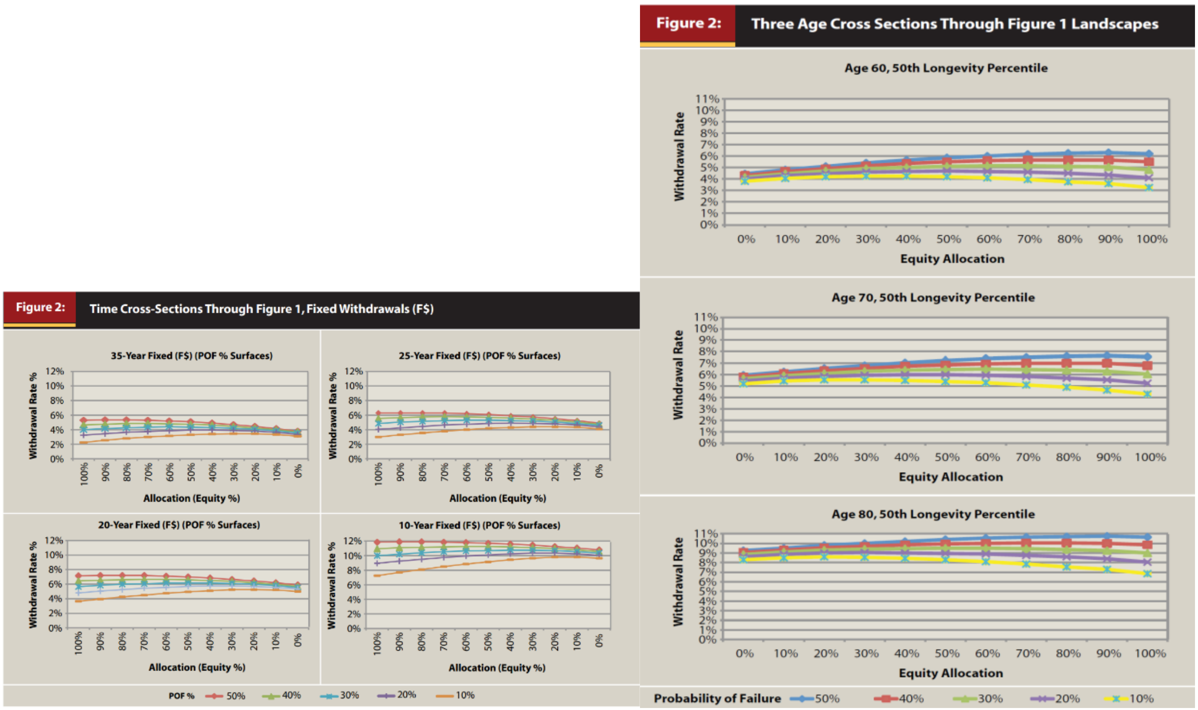

Figure 1. Lower panel. Example of a 3-D "data cloud" and cross sections (Figures "1" and "2" from Frank, et al, 2011 & 2012a respectively)

The upper panel in Figure 1 demonstrates the landscaped relationship between age (time), allocation and drawdown rates with iteration failure rates as the control variable. The 2nd paradigm allows all variable to change, and ignores the one key variable that may be strategically used as a control variable to all outcomes may be compared with other outcomes as seen in Figure 1.

The fundamental perspective of the second paradigm is to set the length of the simulation period, starting with some age early in retirement, typically age 60 or 65, and an end age typically age 95 (typically plus or minus 5 years). Essentially a deterministic determination of time frame through a "speculative" determination of the early-stage retiree's end age, i.e., that "guessed" end-age minus attained age equals simulation time-period.

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Figure 2 contrast today's use of simulations in the 2nd paradigm with the deterministic 1st paradigm approach in the past. Also note the ever-widening dispersion of iterations over the single time period simulated and how those relate to the deterministic determination of the solution, which is at the *beginning* of the simulation, not within or at the end of the simulation. This is true when a control variable is used so that all solutions from different simulations are comparable as discussed below.

To reiterate, the 3rd paradigm begins with an understanding of *where the solution*, (i.e., what is the purpose of running the simulation in the first place) to a simulation resides – that solution resides at the *beginning of the simulation* shown in green in Figure 2. Knowing where a simulation's solution is provides insight to build a model of serially connected simulations.
Also, as will be seen in the third paradigm discussion below, 1) why try to guess as to the end age in the first place when statistics, and statistical percentiles, from longevity tables can do that much better than any guess can, and 2) the longevity bow wave discussion below demonstrates

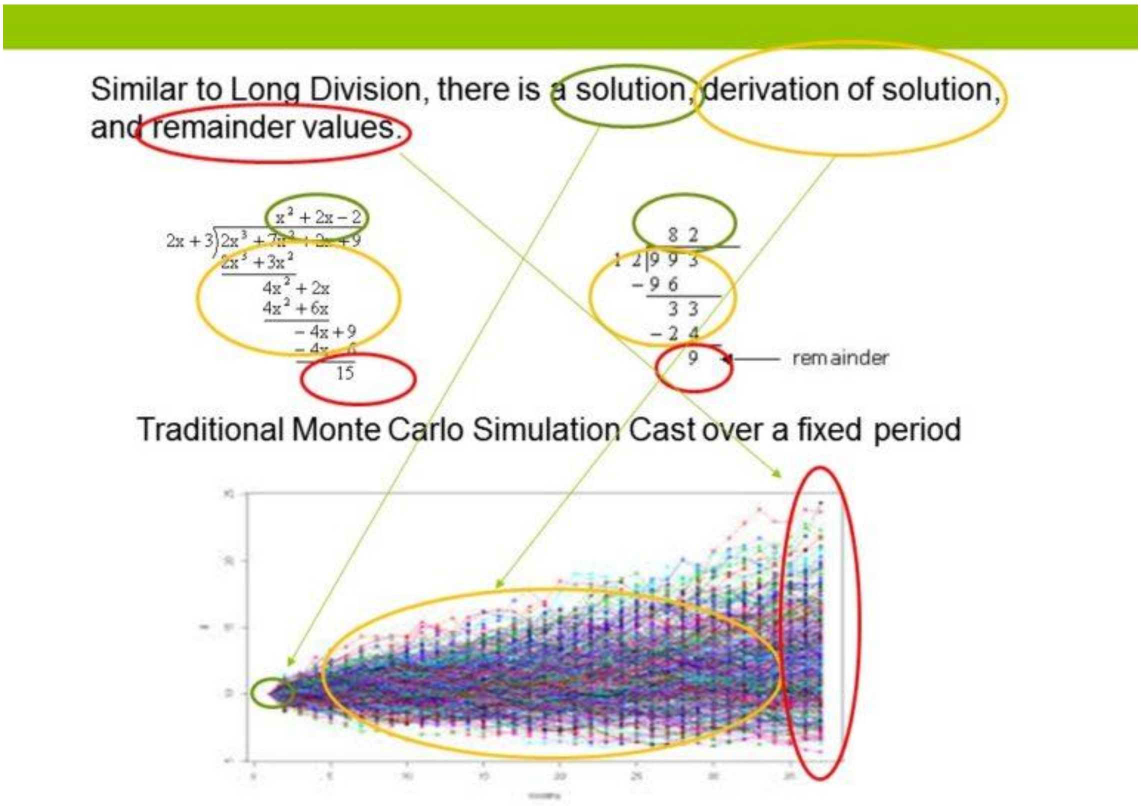

Figure 2. Traditional Deterministic computation compared to a Monte Carlo simulation.

That the resolution of that end age continually, and slowly, shifts with age and thus the proper approach would be to continually roll subsequent simulations into the next time period as a retiree ages. Keeping the end age statistically in front of the retiree regardless of attained age, essentially means dollars to fund those future statistical years are also available, through application of a 90% *iteration* success rate, barring catastrophic spending (10% *iteration* failure rate – not to be confused by the misapplied term "probability of failure" used today … *plan* failure should not be confused with a simulation's *iteration* failure).

Today's second paradigm for software programming is redundant as seen in the series of questions below. One needs to rerun the simulation with those different inputs for those different questions (or worse, change those inputs within the same single factor simulation). Software programming should focus on clearer answers to give people better focus, rather than simply accepting greater uncertainties (wider iteration dispersion) over time from **redundant simulations** that rerun iterations rather than looking deeper into time period and allocation differences using a control variable so outcomes can be directly compared to each other with that common factor (iteration failure rate is that control variable and common factor (Figure 1); not the other inputs which are the variables one wishes to make comparisons).

The single, one and only, uniquely sensitive variable across age and allocation that signals spending health IS the iteration failure rate, as seen in Figure 1. It is misused and ignored in the current paradigm but is the doorway to the 3rd paradigm. Because drawdown rates change with age (time-period), rule of thumb guardrail adjustments aren't consistent for those time periods because shorter time-period differences haven't been researched for those older age, late-stage, time periods (or longer time-periods, early-stage, for that matter). Instead, using iteration failure rates, for example 25%, self-adjust for age, relative to the baseline failure rate of 10%, as the time periods slowly reduce with age. (Frank, et al., 2012a)

Why use rules of thumb when each year's decision points can be specifically calculated? Specifically, it is the iteration failure rate that signals health of spending, not the drawdown rate itself or some percentage change in drawdown rate rule of thumb. In fact, the IFR also signals a prudent optimal allocation by age as well (Figure 1).

Running yearly cash flows and yearly balances *within* a single simulation does not provide the same cash flows and balances that come from cash flows and balances *between* simulations. The later represents what advisers and retirees actually do *as they age.* However, this today is simply redoing the calculation each time *when it is time a review is desired* (Figure 2). It is NOT looking into the future with better focus; only telling us about today when the simulation is run, how we're doing today.

The second paradigm today simply answers today's questions and does little to answer questions about the future, because iterations become more dispersed when only one simulation is performed as seen in Figure 2's "derivation of the solution" (yellow circle).

The questions: Here are questions people have about retirement that generate anxiety about their futures.

- What about other time frames (not just 30 years) that represent my possible future?
- **Why pick a "random" end age such as age 90, or 95, or even 100; when there are statistics that should be used**, **to determine that "end age" for simulation purposes (for people who continue to live as they continue to age)?**
- If one uses a "fixed" age, and recognizing that age will be different for a 60-year-old than an 80-year-old, when and how does one transition from the younger age to the older age to end the simulation period?
- Why not establish a transitioning protocol from the very beginning?
- What about other portfolio characteristics; other than the statistical values used in the simulation?
- What portfolio allocations are within an efficient allocation range?
- What other portfolios have different statistical characteristics; shouldn't those be evaluated too?
- And thus, at what later age should the portfolio be adjusted from the initial allocation to a later allocation, and even later, as one ages?
- What's a prudent gross cash flow in the first place? Before considering making spending choices and taxation?
- What does the statistical range of spending throughout retirement look like, regardless of age now, or in the future?
- How can statistical spending characteristics of retirees be compared by select spending categories and cast by age into the future for each retiree by model? (Blanchett, 2014)

Statistics may also be more refined through the use of metalogs (Savage, 2018, 2021, Keelan, 2021). Such refinement of statistics is an example of applying new approaches from other disciplines where new mathematics helps bring better focus on retiree cash flow and balance expectations into their later ages as they age.

What if statistics change? Paradoxically, the 2nd paradigm ignores this question while asking it about the 3rd paradigm. Three brief thoughts on this question from the author's clinical experience. One: they always have and always will change over time. Two: meaningful statistical changes are subtle and slow in their change process. Three: there is time to incorporate new information through slowly changing statistics through periodically updating the statistics used in the model as the retiree ages prior to (still working and saving) and through retirement. Aging and statistics are not static and therefore statistics may be used to inform decisions at the moment for those years ahead, regardless of present age. The process doesn't change just because statistics slowly do.

Single simulations, with single factors as inputs, don't address the question "Compared to what?" Simulation failure rates do not represent retirement income failure. Single simulations at one age do not represent simulations at a later age. In sum, how may the uncertain future be brought into better focus?

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The Third Paradigm – What Should Be

These questions lead to what I'm suggesting would be the **third paradigm** that would shift and transition current thought and approaches from simply applying a stochastic process over deterministic inputs: a set time period, and set allocation, that currently exist in the second paradigm today. Aging is also viewed in a set and static manner today.

In other words, what is needed is a transition to *model* retirement *aging* across all the future ages a retiree might experience, based on strategic use of longevity table percentiles *by age*, as well as applying the stochastic process to the statistical characteristics of many optimized/efficient portfolios so the software suggests what allocation should be considered *by age* (Frank, 2022a).

This approach begins with having an idea of what the optimal and sustainable annual gross cash flow may be, *by age*, in the first place, and then making adjustments for taxes, etc. for the net after-tax cash flow. Balances are affected by the gross spending from the overall portfolio (including fees based on balances), while retiree spending is net after taxes, net after fees.
Figure 3 is an example from prototype software illustrating cash flows and balances based on optimal, or prudent and sustainable, spending may look like computed at each age. Drawdown rates represented in Figure 3's results are illustrated in Figure 5 (from Frank 2022a, Figure 5).

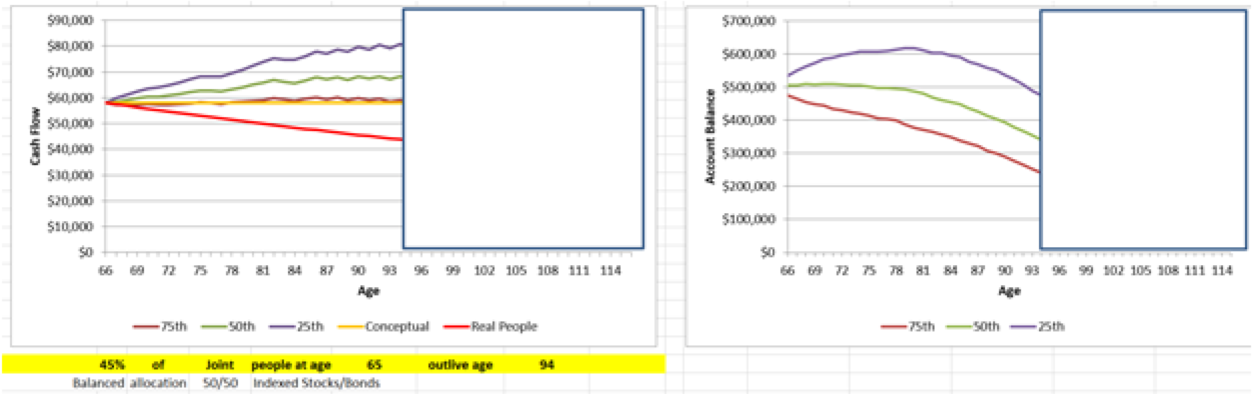

Figure 3. Gross cash flows (left panel) and portfolio balances (right panel) by age.

Adjustments can be made to that initial model, to see what a minimum spending, or floor level, may look like in the model. A maximum spending, or ceiling level, may also be evaluated where more insight may be gained by seeing at what age(s) cash flows begin to drop off (a spending floor is set), or portfolio balances begin to balloon (a spending ceiling is set). Below is an adjustment to the above example, but now with a set ceiling, or constrained spending (constrained to 5% drawdown rate) (Figure 4):

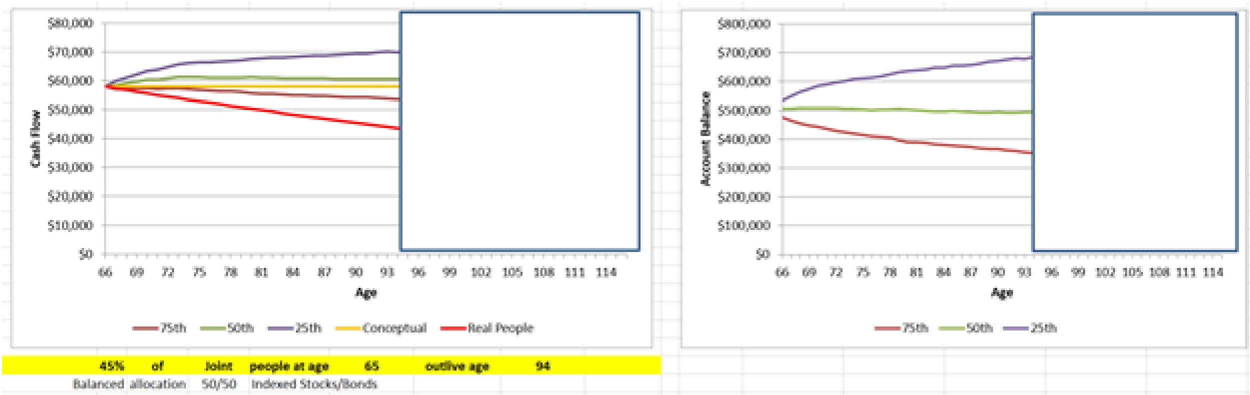

Figure 4. Cash flows constrained to 5% drawdown ceiling (left panel) and resulting portfolio balances dispersion.

Notice how the cash flows and balances in Figure 4 now resemble today's single period longer term wide Monte Carlo simulation *cone shaped* dispersion patterns between the simulation percentiles (between 75th or *consistently poor returns,* and 25th percentiles or *consistently good returns*) … as compared to Figure 3. This is because the 5% drawdown rate ceiling, when set at a "low value" relative to possible drawdown rates at later ages, soon becomes the floor spending as well. Since floor and ceiling spending are the same, the ever-widening iterations dispersion at later ages results (Frank, Brayman, 2016). Today's simulation, again 2nd paradigm graphs that are in use presently (e.g., Figure 2), now show an ever-widening uncertainty between upper and lower iterations like results seen in “constrained” spending in Figure 4, rather than more focused by age range of future visibility for better decision making today as contrasted in the Figure 3. Wider dispersion equals more and more future uncertainty which behaviorally makes clients less comfortable – the opposite of what the profession, and support software programming, should provide! More research is needed using an age-by-age modeling approach between annuity purchase (Frank, et. al., 2014) (combined with pensions and/or Social Security) interaction with floor and ceiling effects discussed in Frank, Brayman, 2016. Additional research on exploring modeling portfolio cash flows versus alternative annuity purchases, or using the portfolio to bridge to a later annuity purchase, age by age may help people avoid hyperbolic discounting behavioral errors.

Figure 5 illustrates the age-by-age drawdown rates used in Figures 3 and 4. Figure 5 is discussed in detail in Frank, 2022a. Figure 5 illustrates the ever-changing nature of drawdown rates as strategic longevity percentile, discussed below with Formula (1), derived time periods shorten with age. The 2022+ IRS Required Minimum Distribution (RMD) rates are also illustrated to demonstrate the same effect using a different methodology to determine drawdown rates (a tax agenda versus stretching assets to outlive the retiree agenda as described in this paper).

The allocation values illustrated in Figure 5 are using historic asset class data with allocation values representing equity/bond mixtures of those efficient allocations shown in Appendix 1. This ever-widening dispersion, or cone shape, is also what creates the illusion that sequence risk goes away over time and is simply because spending is constrained as in Figure 4. Is that the retiree’s goal, to restrain spending? Inadvertently this means over saving for retirement in the first place as well as tilting the goal to heir bequests. Is a bequest the retiree’s goal? The contrast between Figures 3 and 4 is an example of how an age-based longevity driven paradigm brings more focus to those later state range of results. A retiree can see how a deeper discussion about the present versus the future come about with modeling versus single period simulations is use at present.

Sequence risk is always present at all ages since it happens *concurrently* (at the same time) for *everyone* invested in the markets, at that moment, regardless of age (and any firm investing in any market), retired or not retired. It’s not sequence risk; rather it’s better thought of as *Downturn Risk*. This is discussed more below in the retirement “red zone.”

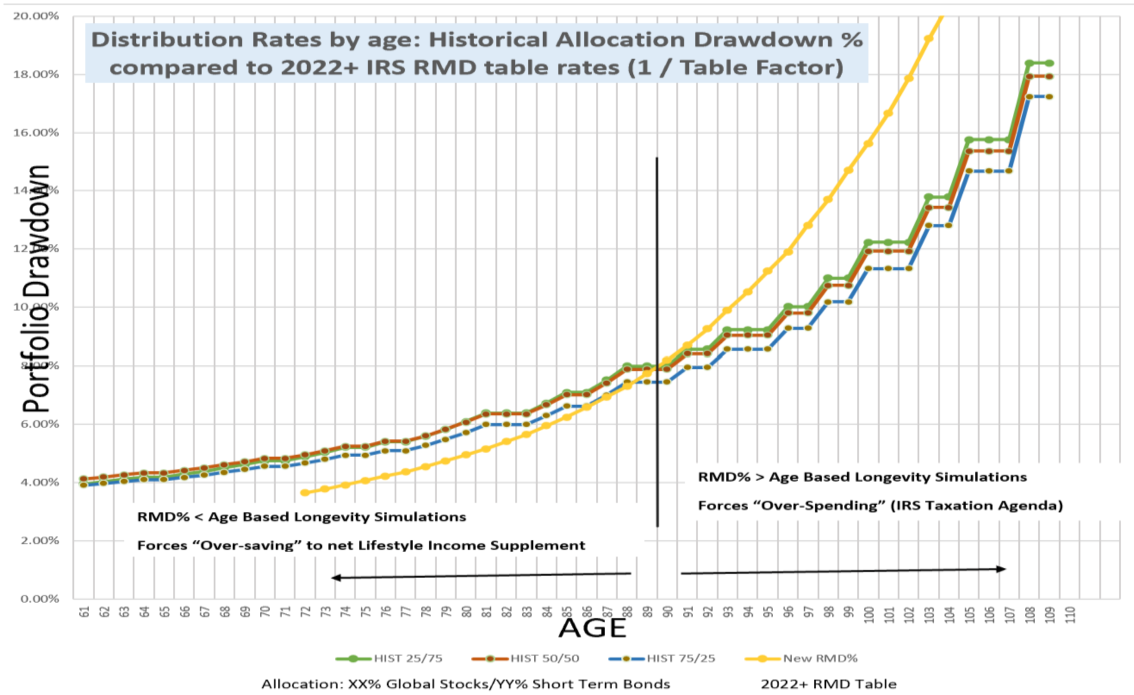

Figure 5. Comparison of IRS RMD 2022+ Distributions with Longevity & 1-1/n Adjustments to “Raw” Drawdown rates. (Frank, et. al. 2012b & Frank 2022)

Modeling provides focus and insights that measure and monitor sustainable and prudent consumption as long as each retiree lives. Modeling also provides insights into meaningful measures and adjustments to take *when* the markets take a *meaningful* downturn (sufficient change in iteration failure rate corresponding to the rise in withdrawal rate from fixed dollar withdrawal amounts).

What are the Three Paradigms of Retirement Income Planning?

These two sets of example graphs demonstrate the tradeoff between spending (Figure 3) versus balance retention in Figure 4 (for heirs? or the retiree's own higher spending at later ages). In other words, in the spending-constrained figure (Figure 4), the outcome is higher balances, as well as possibly a shift to greater equity allocations, resulting in more for later spending or for heirs, or both. Or, with continually poor market returns consistently year after year, lower balances resulting in lower spending capability, in other words the opposite of consistently good market sequences year after year. Different answers for different retirees depending on their individual and unique druthers; druthers that should be each retiree's choice, after seeing through modeling software the linkage between cash flows and balances *by age*.
Figure 8 expands on these concepts and shows how age, shifting longevity, and allocation characteristics slowly transform "the picture" of cash flows and balances *as one ages.*

For now, suffice it to say there's a direct linkage between spending, balances, and allocations *by age* that can be modeled for better clarity and focus for advisers and clients – the third paradigm.

Introducing the concept of rolling longevity *with aging*.

The Longevity Statistics of Aging … The "Longevity Bow Wave"
Statistics in longevity tables are not static *as one ages through the tables.* Rolling use of longevity table statistics based on attained age, combined with a *strategic* use of longevity percentiles, results in the retiree(s) money outliving them (barring catastrophic spending), since there are always statistical years in the tables based on attained age, at least to 120 in some tables, which means using the tables strategically *by age* means money to fund those statistical years ahead of attained age is also available (*combined with* using the control variable concept with iteration failure rate discussed above).
An analogy: there is always a bow wave in front of a moving boat. The boat never catches the front end of the bow wave. The bow wave always exists in front of the boat until the boat stops! The beginning of a simulation is similar to the front of the boat in this analogy.

Figure 6 panels illustrate the **"longevity bow wave"** using a strategic use of longevity percentiles. Figure 7 shows the "big picture" summary of Figure 6 of how aging changes the time frame over which simulations need to be run. Each retiree ages into the next time period and each time period is slightly shorter than the prior.

Objective of the **strategic use of longevity percentiles** is to roll, i.e., model the aging effect, into lower and lower probabilities of outliving the corresponding end table age for each attained age. The modeling strategy makes it **more and more *<u>un</u>*likely that the retiree will outlive their money**, barring catastrophic spending, while still *being able to optimize spending during those years they're still alive at ANY AGE*. What this eliminates … *guessing* or *picking* some arbitrary end age, typically age 95 +/- 5 years.

The 2nd paradigm approach leads to arbitrary inputs with arbitrary results in the simulation using a single factor for the Monte Carlo time function on top of the single factor simulation of just one portfolio. What about other time periods and other allocation characteristics for other models (or even portfolio statistical characteristics of the not-yet-client "inefficient" allocation?). **Why not just let statistics determine the table end age to derive the time-period for the stochastic calculations?**

Figure 6 panels show how the ending table age slowly moves older and older as the retiree ages. Ending table age changes from age 93 to 107! It's NOT a static age 95! Why does it matter? You can see the effect on the drawdown % (DR%) in the data cloud data and the fact that WHEN (at what ages) an allocation adjustment may be suggested by the data and methodology itself (both effects not seen under today's paradigm). Oh, most people think that the table end age is when money runs out! Remember the use of 10% iteration failure rate? That translates into 90% of the iterations outlast that table end age! **Figure 7 illustrates how longevity and aging affects the decreasing rolling time periods which affects simulations too!**

The methodology (Frank, et al., 2012b) for strategic use of longevity percentiles is starting with expected longevity, defined by the 50th percentile, at age 60, where 50% of those age 60 (joint, or single) *outlive* the percentile age. Note that each age after age 60 that the table expected longevity age is *younger* than the strategic percentile age. In other words, expected longevity (50th percentile) is by definition younger than "right tail" age where a smaller percentage of cohorts are expected to outlive that older age. Age 60 is selected as a starting point for retirement purposes. The starting point for strategic use could be any age, but age 60 makes the strategy tie closely to the decade retirement may begin and thus more practical to implement *as the retiree ages* as explained here. What is the 50th percentile end age in the Figure 6 Panel? Age 93. Then decreasing the percentile by one per year per year aged, results in the 40th longevity percentile by age 70, where 40% *outlive* the percentile age of 95. The methodology continues as long as the retiree lives to 110 where the annual longevity percentile decrease stops.

Formula for Strategic Longevity Percentile (SLP) determination:

$$SLP = 50 - (\text{Attained Age} - 60) \quad (1)$$

60 represents the *baseline age* that starts the process. 50 represents the *50th percentile*, where half the cohort predeceases that age and half outlives that age, which again is the definition of expected longevity *for each attained age.* The SLP determined age is an age where a *smaller* percentage of cohorts *outlive* that age. Moving the SLP slowly by percentile each year makes the probability of outliving that SLP determined age less and less likely. This is illustrated in Figure 7. This process application results in cash flows seen in Figures 3, 4 and 8.

Example using Figure 6, Age 80 Panel: 50 – (Attained Age 80-60) = 50-(80-60) = 50-20 = 30th SLP. The 30th SLP corresponds to Age 97 in the table used for *either alive* of a joint couple. Thus, the drawdown time-period is age 97 minus age 80 or 17 years for modeling cashflow and balance at that age. Cash flows and balances last beyond that age determined by the methodology where iteration failure rate 10% means 90% of iterations successfully go beyond the 17-year timeframe in this example, and that timeframe is one where 30% of age 80 cohorts in this example outlive. This process is used to *determine the time-period for each age and every age in the retiree's future, by determining the end age using the SLP methodology*, which is applied in a rolling manner for every attained age modeled from longevity tables.

A joint longevity is selected in the graphs simply to "force" the longevity illustration software to show "client" and "co-client" as well as "both alive" ages to demonstrate more traditional male and female longevity ages simply to illustrate younger ages would result for singles (not married or living together) for those same longevity percentiles in each panel … result would be shorter simulation time periods calculated for the model and thus higher drawdown rates relative to the other illustrated client-type. Likewise, a less healthy person would have a shorter life expectancy than a healthier person and thus have a higher drawdown rate in comparison even though they are the same age. Matching the drawdown period to the retiree is therefore a key factor for each retiree's model. The exponential effect on RMDs seen in Figure 5 is resolved for the age-based methodology by using an adjustment factor 1 – 1/n where n equals the number of drawdown years simulated (Frank 2012b).

Continuing to *decrease* the strategic percentile age by age results in *slowly* rolling the retiree into later ages they are less and less likely to outlive. *Therefore, tilting more spending into early years the retiree is more likely to be around to spend, and slowly adjusting spending down as the retiree ages and/or are less likely to outlive their remaining funds.* Many planners become concerned about such a tilt, however *that's the retiree's choice* once they are better informed, which is the purpose of the modeling-by-age discussion through this whole paper. The ceiling and floor modeling discussed above illustrates how modeling *by age* provides these insights to both the planner and retiree.

Figure 6: Age 60 Panel: Expected Longevity by definition 50% (50th Percentile) where ~50% OUTLIVE table age (in this case, age 93)

Figure 6: Age 70 Panel: 40th Percentile = ~40% OUTLIVE table age (expected longevity or 50th percentile Younger than that)

Figure 6: Age 80 Panel: 30th Percentile = ~30% OUTLIVE table age (expected longevity or 50th percentile Younger than that)

Figure 6: Age 90 Panel: 20th Percentile = ~20% OUTLIVE table age (expected longevity or 50th percentile Younger than that)

What are the Three Paradigms of Retirement Income Planning?

Figure 6: Age 100 Panel: 10th Percentile = ~10% OUTLIVE table age (60-year old's don't worry about 107, but 100-year old's might (what if they're the 1 out of 10?) (expected longevity or 50th percentile Younger than that)

Figure 7 compresses all the Figure 6 panels into a single illustration or a "big picture" visualization of the "longevity bow wave" aligning attained age of lower panels to that same age in an upper panel. The result of ever-shorter time periods is ever-higher drawdown rates illustrated in Figure 5 (all drawdown rates are at 10% iteration failure rates). Figure 7 drives home how the distribution time-period changes, as well as how the longevity percentiles change, as the retiree ages from early-stage retirement years to and through later-stage retirement years.

It is the application of the statistical longevity bow wave derived time periods illustrated above, that results in the cash flow and balances graphed in Figure 8.

Figure 8 panels by age are quite different from Monte Carlo simulation illustrations of today because the **illustrations here incorporate both "probability of the portfolio" (portfolio statistics) with "probability of the person" (longevity) in a unified model.** Recognize as well, there are ten yearly transitions between each illustrated 10 year "snapshots," but not illustrated specifically, so that the transitional points don't clutter the illustrations in both Figures 7 and 8. Each of those 10 transitional points represent aging, one year at a time, between the snapshots illustrated. Modeling software (Frank, 2022a) would perform each year's calculation for each year attained to "smooth" the transition cash flows and balances year by year to represent modeling aging. This paper discusses the "why" of retirement income planning paradigm shifts and Frank, 2022a discusses the "how."

What is the fundamental difference between the second paradigm we're presently under, and the third paradigm?

Today's present or second paradigm counts time up numerically. The paradigm's point of view is "years in retirement," or "years since retirement." Result: short time periods come first with longer time periods at the end. The third modeling paradigm counts time periods down to model aging. Long periods come first with shorter periods later … as seen in the longevity bow wave Figure 7. The third paradigm's point of view represents aging. The second paradigm's point of view is a Monte Carlo application to a deterministic point of view carried over from the first deterministic paradigm.

The point of measurement in the third paradigm is always the retiree's present attained age and looks forward into statistical life through a strategic use of the life table percentiles described above. For review, expected longevity by definition is the 50th percentile. A 60-year-old may use the 50th percentile from the life tables. A 70-year-old may use the 40th percentile where 40% statistically outlive that table derived age. An 80-year-old may use the 30th percentile where 30% statistically outlive that table derived age. This Xth percentile use may be used strategically one year at a time to slowly make it more and more unlikely the statistical age might be outlived. As long as a retiree is alive, there are statistical years ahead that need funding. The statistical bow wave continues ahead of the retiree regardless of age. This is in lieu of the present paradigm's practice of "picking" some random end age implied by a random drawdown time frame over which to cast that single factor simulation.

Note the prototype software example of aging model incorporating both portfolio and longevity percentile statistics along with consumer spending trend line of "Real People" (which is not based here on spending percentile statistics, but on research averages (Blanchett, 2014). Starting balance $500,000 with $36,000 Social Security. Two simple graphs by age answer many retiree questions about potential future spending and balances. Creates a whole different discussion. Also illustrates why age 95 is a poor reference for planning since it doesn't plan or consider aging into future ages *from the beginning of retirement.*

An example of aging, and modeling aging, is graphically illustrated in Figure 8 using prototype software. It illustrates why using a set age as a reference is a poor planning process. Figure 7 illustrates the "bow wave" of aging as long as a retiree is alive, there are statistical years ahead of them requiring supplemental income. Any life table may be used, since all are subsets of the

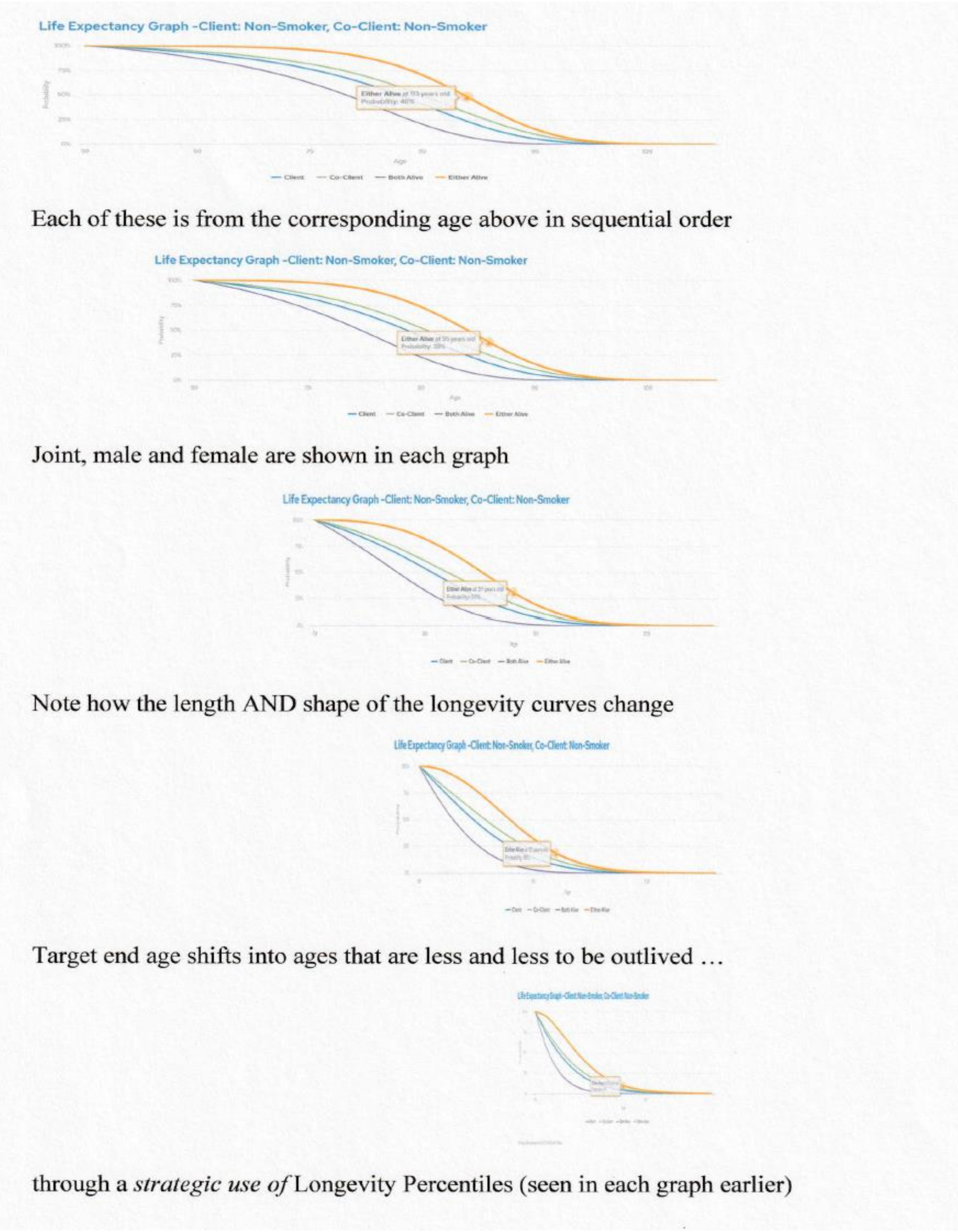

Figure 7. Panels of Figure 6 compressed onto a single page for comparison shifts in time.

same population, to determine longevity percentiles that are illustrated for each age via percentages who outlive end-of-simulation-determined ages, which set the time period the simulation covers, but in reality, the main point is the actual end age keeps moving out as the retiree ages in a rolling time frame and simulation period protocol.

Note that allocation aggressiveness goes down with age in Figure 8, i.e., a FALLING GLIDEPATH, which is what Kitces/Pfau (Kitces, Pfau. 2015) had in their data on the glidepath research if they hadn't arranged the data counting years up (i.e., 2nd paradigm), but instead of counting years down (i.e., 3rd paradigm). Bengen's own research showed higher drawdown rates for shorter periods (Bengen, 2006). What was missing in the 2nd paradigm was how to order the data; short to long, or long to short? In other words, Kitces/Pfau RISING glidepath for allocation is a result of HOW the data was arranged. Figure 8 shows cash flows and balances by age (not time *since* retirement, or *in* retirement). How much portfolio risk should any retiree have? The data cloud approach (Frank 2022a) answers that question at any age by indicating the optimal allocation providing optimal cash flows. Redundant simulations no longer need be run if simulations have already been run for all allocations and time periods and retained in a data cloud which is updated periodically as described in Frank 2022a.

Notice in Figure 8 that the range of uncertainty, the spread between the upper 75th cash flow and balance percentile and the lower 25th percentile narrow with age, due to both the shorter
timeframe combined with more conservative allocations. See Appendix 1 for allocation and asset class details.

Transition between time periods was not explored by Bengen, or through the heuristics that followed. That transition between any and all time periods is explored below through a modeling by age approach that can easily be adopted into software programming (Frank, 2022a).

So how should time periods be considered? This is a key question, and the answer is critical to the transition from the 2nd to the 3rd paradigms. This counting years method is another paradigm prevalent in the profession at the moment whereby viewing *years SINCE retirement, or IN retirement, rather than years REMAINING in retirement.* This counting-years-up methodology is akin to saying "the further back I compare myself to, the better I am now." The "Red Zone" (Mirolli, 2019) perspective results from the disconnect that presently exists between saving years and spending down years.

The current paradigm yielding the red zone view can't connect the transition between the two phases with a unified model approach, between the working accumulation years and the retirement spending years, because neither phase is presently age based, but rather is based on a flawed paradigm emerging from counting years up described above … which leads to a view that sequence risk of returns exists only at the time of retirement, plus or minus some years of transition. The risk of *market downturns* exists simultaneously for all retirees regardless of age. Thus, some other methodology is needed to address actions for those events, such as suggested above using the iteration failure rate methodology discussed in Figure 5 and further discussed next.
Figure 8's aging illustration also shows spending and balances in today's dollars, using real returns, with desired upside spending, or suggested downside spending, ranges depicted using yearly modeling percentile ranges between 75th and 25th percentiles (consistently good and consistently poor markets) with the median 50th percentile in between. Drift into less than 50th percentiles would signal spending adjustments to retain more shares (selling shares at lower prices means selling more shares to net the same dollars). Rerunning the model program for attained age would suggest to what gross spending amount may be desired. Note that the percentile spread in the prototype software is probably wider than a more pragmatic narrower spread such as the 60th and 40th percentiles. Selection of the three percentiles to depict, with the median or 50th percentile being a main default, would allow the retiree to view other possible continuous market scenarios dispersion ranges. For example, if the concern is continually declining markets, then the 50th, 40th, and 30th percentiles may be selected for those less-than-median return years may be viewed. The "cover" over later ages 1) moves slowly towards older ages to reveal both spending and balances at those older statistically derived ages, 2) may also be "uncovered" to show retirees those older ages during plan discussions (not uncovered in graphs), and 3) shows as long as there is statistical life possible, cash flows and balances model to "end of the life table" barring catastrophic spending. Thus, the question on longevity estimations commonplace today – why even try to guess how long one might live? – when one can use statistics strategically to keep the longevity "bow wave" continually ahead so one outlives their money, barring catastrophic expenses.

The illustrated concept in Figure 8 is to follow the prudent spending *percentile range* year by year as one ages. Cash flows are gross income before taxes. Different income levels would be programmed for net income spending after applicable Federal and

States taxes. Floor or ceiling concepts are not illustrated; only the prudent income as a starting level in the first place. Lumpy, floor or ceiling spending effects would ripple through later ages if applied (Figure 4).

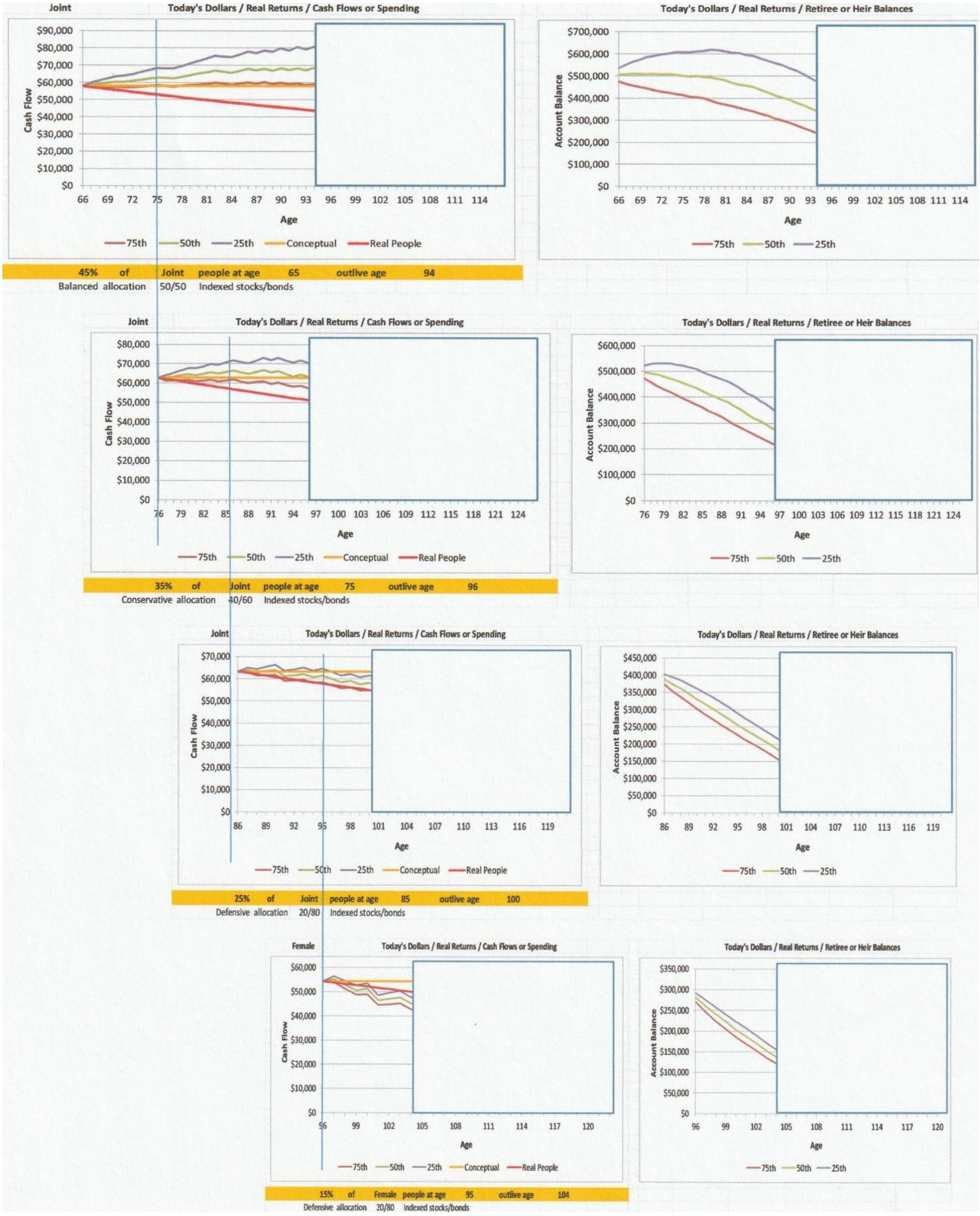

Figure 8. Cash Flows (left panels) and Portfolio Balances (right panels) Aligned by Age

Floors and/or ceiling spending obviously constrain spending cash flows while unconstrained spending more reflects variable spending. Retiree choice should come into play in the decision-making process using a model that combines constraints, or no constraints, to cash flows *by age.*

In sum, the graphic modeling that most closely resembles the third paradigm combines both statistical aging (Probability of the Person(s)), along with portfolio statistics (Probability of the Portfolio) as well as consumer spending statistics (Blanchett 2014).

What are the Three Paradigms of Retirement Income Planning?

People are more interested in their future than they are in their past on the topic of retirement income for their future, for this year and all the other future years. This future oriented interest exists at all ages and includes pre-retirees saving for retirement as well as retirees spending during retirement. The age-based paradigm, and modeling based on it, smoothly transition people from working to retirement at any age, based on the same methodology.

Cash Flows and Balances While Aging … with the Longevity "Bow Wave" Incorporated

The illustrated age-based model below recognizes aging, where start ages and end ages shift

slowly in a rolling year by year manner as one ages, and that shifting time frame changes simulation results for each age (simply because of the changing time frame for each simulation period), and thus insights for decision making also changes as one ages.

Note again in Figure 1 that the short time periods are at the end of the time series, not at the beginning as interpreted by the current 2nd paradigm of counting years up or years in retirement. Also note the changing allocations over time in between each panel in Figure 8, getting more defensive as one ages (as noted above/below how the data was arranged under a counting-the-years-up paradigm in the Kitces/Pfau study. If their data were to be arranged with short periods last representing aging longevity, the same allocation glidepath to more defensive is observed – i.e., a declining glidepath is in their data). Note that the allocations depicted in Figure 5 also suggest a declining glidepath.

Note below how the time periods slide from left to right simply because the shorter periods are at the end of the aging cycle. The prior age modeling has the later age modeling within the boundaries of the 75th and 25th simulation percentiles simply because each age and allocation simulation has been previously run. Just as in the longevity bow wave illustration above, recognize as well, that between each of the 10 year "snapshots" there are 10 annual computational points represented for both cash flows and balances, but not illustrated specifically, so that the transitional points don't clutter the illustration. Each of those 10 transitional points represent aging, one year at a time, between the snapshots illustrated.

Many people wish to retain their principal throughout retirement. However, how much principal do you need when you're in your 80s or 90s? Answer: enough to last the rest of your statistical life (which turn into bequests eventually).

Notice the cash flows, unlike today's 2nd paradigm simulations, that later age projections are near the projections for those ages in the earlier age projections. That is not what today's 2nd paradigm projections show because they are not modeling aging, but instead are single period simulations. This helps refine modeling cash flow tax impacts as well.

Figures 7 & 8 together illustrate how aging moves the simulation time frame from earlier stage retirement ages to later stage retirement ages. There's a rolling period dynamic effect of aging moving from longer timeframe drawdown periods to shorter timeframe drawdown periods as retiree ages. This ever-shortening timeframe period length has a direct effect on the cash flows since shorter drawdown periods have higher drawdown rates (Figure 5), which then has a direct effect on portfolio balances. The aging process makes retirement income planning much more dynamic than presently viewed under the current (second) paradigm. A paradigm shift into a third paradigm takes they dynamism of aging and the illustrated effects into account.

Note the cash flow graphs on the left panels in Figures 3, 4 and 8, have a "Conceptual" line which represents the concept of level consistent spending, and a "Real People" line which represents evidence of spending patterns (declines) as one ages (Blanchett, 2014). The prototype software demonstrates it is possible to compare all of those by age for better clarity for discussion and retiree decision making *as they age.*

Consumption smoothing of cash flows is possible when done age by age showing cash flows after lumpy expenditures for future spending post lumpy expenditures. How might a deferred annuity income at a later age compare to portfolio income at that age? Note that purchase of a deferred annuity also means that purchase amount is not presently available in the meantime – so what is the lost income between now and the deferred age of that purchase, compared to not having purchased the deferred annuity in the first place?

Modeling cash flows *between* simulations focuses more clarity on what future cash flow ranges may look like through using simulation percentiles to illustrate upper (good markets), median, and lower (poor markets) cash flows as well as future possible portfolio balances (Frank, Brayman, 2016). Note too, that Social Security and/or pensions would be included as part of those cash flows. Impacts on survivor cash flows (reductions in income from Social Security rules, or poor pension options or choices) are also seen with more clarity too.

There is no *plan* "failure" other than more refined degrees of funding compared to client defined desires such as spending floors, ceilings, or adjustable spending relative to consumer spending statistics. Failure is an old term of the 2nd paradigm, referring to simulation iterations, and not part of the vocabulary of the 3rd since failure typically is understood to be running out of money prior to running out of life. A better approach would be to establish modeling by age and evaluate a *floor* spending level where spending may not drop below the statistical percentile of spending from the Consumer Spending Survey based *on retiree ages as they age* (i.e., the Real People line example in Figures 3, 4 and 8).

Finally, further research is needed into comparing cash flows from a portfolio *by age*, with cash flows from an annuity *by age* purchased, as well as future cash flows from both, because purchase of annuity income requires use of some portion of the portfolio balance and thus the question becomes, how does the total cash flow *by age of* the portfolio, without annuity purchase compare to total cash flow *by age of* the remaining portfolio (if any) plus the annuity after purchase. Simply performing this comparison once at an earlier age ignores how delay of an annuity purchase to a future age may enhance cash flows and balances *afterwards* (Frank, et. al., 2014).

The missing link between working-saving years, and retirement-spending years.

An age-based longevity approach eliminates the perception of a so-called retirement red zone because volatility and returns sequences actually exists at all ages. Establishing statistical measures using simulation percentiles to signal good or poor spending and balance health and sustainability (Figure 1's lower panel illustrates increasing iteration failure rates signals spending risk through rising drawdown rates since iteration failure rates and drawdown rates are directly related), also come from an age-based model protocol as discussed in the 3rd paradigm. In other words, establishing a longevity, age-based, methodology where rolling time periods based on attained ages each year, is used from the first year (young age) of saving for retirement all the way through to the end of the longevity tables. This methodology connects the saving with the spending phases smoothly and transitions between the phases at any age – simply because the longer time periods are kept in front of the shorter time periods throughout the rolling age longevity-based methodology, regardless of age.

Example: "If I were to retire today at age (insert age here: e.g., 40, or any age), how much would I need to save for that sum of money to last throughout retirement as long as I live? How much extra do I need to save to bridge me to when my Social Security (and/or pension) starts? At what age do my savings, Social Security (and/or pension) accumulate sufficiently to retire and sustain my desired lifestyle (Standard of *Individual* Living (SOIL), (Frank, 2005)) through retirement. A specific lifestyle measurement is more specific to people than an average percentage reduction is spending from income replacement ratio approaches. What are the meaningful levers the retiree has to adjust those results, not only until retirement, but also during retirement? What is the dynamic effect on lifestyle and retirement feasibility simply by saving more?"

Note that saving more moves the lifestyle goalpost lower since the pre-retiree's lifestyle has become accustomed to saving more and thus living on less. Second paradigm software does NOT make this adjustment, or the ripple effects adjustments, that result from this single simple change in lifestyle.

How about ordering data according to attained age and the longevity, and even longevity percentile, associated with it? As soon as one brings in longevity statistics (incorporated into below illustration) so one is counting years forward while *also considering corresponding age-based time periods*, the time-period numbering protocol for simulations on the time axis reverses, from counting lower to higher, to counting higher to lower because one is using time period lengths corresponding to the time period each age has derived from life tables. In other words, years *since* retirement puts the long-period simulations at the end of the data series, BUT long-period data series should be placed at the *beginning* because those *are the* longer periods, with shorter periods corresponding to older ages, as seen in the age timeline in Figure 7.

Modeling in this paradigm would also provide more clarity to sporadic cash flows, such as buying a new car later in retirement with either all cash, or all loan, or some mixture, by comparing how cash flow and balances affect desired retiree outcomes (more cashflow now, or more bequest later).

What are the Three Paradigms of Retirement Income Planning?

A real retiree example.

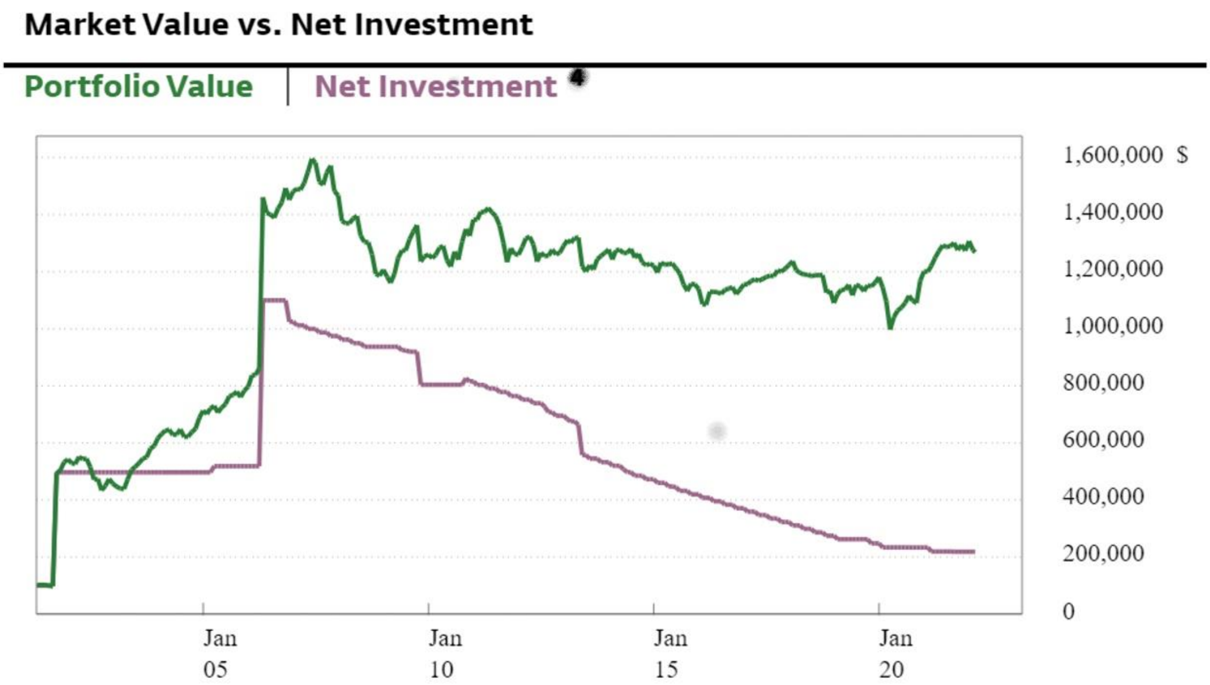

Figure 9. Balances (green) and cash flows (purple) since 2001 of an actual retiree to 2/2022.

The application of the concepts in this paper are derived from nearly three decades of clinical application and observations with actual retirees, and for a broader and fuller application to transition to the 3rd paradigm applied through prototype software programming proposed in Frank, 2022a.

Figure 9 illustrates a real retiree applying the 3rd paradigm methodology of this paper and prototype software discussed in Frank 2022a, with balances as they aged (green line) and contributions/steady drawdowns seen by steady slopes of the purple line. Net investment is net after all contributions (since 4/2001), withdrawals (since 1/2007), and fees (since 4/2001). The gap between portfolio value and net investment represents the total return of the portfolio for *future* supplemental income withdrawals. Drawdowns, computed via the methodology discussed above and Frank 2022a, and fees, come from the portfolio value. Had there been no withdrawals, the portfolio value would continue to slope upwards based on actual market returns. The allocation has been Balanced (Appendix 1) during the entire period. The "9/11 Recession," "Great Recession" and "COVID" along with all other intervening events are seen on the green line. Other retirees' are similar in long term experience with the exceptions of age, allocation based on age, portfolio values and/or when they transitioned from accumulation to drawdown and subsequent global market and economic events.

How to transition to the third paradigm?

Researchers and planners today operate using today's 2nd paradigm described above. Today's planners are unaware of what they could ask for as far as better modeling software for income, or cash flows, and balances. Cash flows and goals can be integrated better. Rather than running redundant simulations, all the *simulations should be run one time and the data archived* for programming use (easily done if software programming was focused on doing this task). Planning software programming could then be refocused on iteration percentiles representing consistently good markets, median markets, or consistently poor markets so as to better visualize the range of possible cash flows and balances outcomes by age, out to the end ages of longevity tables, some of which go to 120. In other words, planning software would then focus on what advisers and retirees are really interested in by age in the future in a narrower and better-connected series of cashflows and balances.

This approach results in cash flows and balances *by age*, even out to the end of longevity tables (some go to age 120). A strategic use of good, median, and poor market simulation percentiles narrows the range of outcomes in the future to those more likely to be experienced. Future reviews continue to narrow those uncertain futures with future updates to statistical data. Many may think why 120 when most don't live that long. Computing well past ages today illustrates that there is money out to those older ages, barring catastrophic spending. It also demonstrates the need to keep the estate plan up to date, not only from the point of view of the retiree(s), but also from the point of view of the estate planning lawyer as laws, or even the interpretation of those laws, change over time. This removes the worry people have of outliving their money and helps them focus on real needs and wants.

SUMMARY

Cash flows and balances *within* a simulation are NOT the same as cash flows and balances *between* simulations. Planning today has a static perspective with static time periods and considers aging *within simulations* as sufficient. Cash flows *within simulation* attempts to age a retiree *within that simulation* too. But aging occurs *between simulations* in real life because advisers rerun simulations over time for people; advisers don't refer to the old simulation to evaluate spending now later on – they do a new one. Thus, modeling cash flows *between simulations* more closely captures aging as shown above. Also, since advisers have more than one client, all at different ages, modeling all ages and allocation characteristics for a "data cloud" (Frank 2022a) of results, software programming power can be more efficiently utilized for modeling present and future optimized cash flows, rather than performing redundant simulations just for today's age and allocation one at a time for each retiree one at a time.

The third paradigm embraces aging specifically with rolling time periods, each of different lengths of time based on attained ages, uses the longevity table percentiles strategically, and replicates retiree cash flows and balances as they age, so as to model cash flows and balances *between simulations* since that is what actually happens in real life.

The third paradigm is modeling which brings more clarity and focus on the questions relating to planning for supplementing retirement income from investments, Social Security, and/or pensions in a combined manner. One can look at the "Cash Flows and Balances by Age" figures above and have a better focus and clarity on the range of possible future outcomes. The ripple effects of small spending changes in the plan can also be seen with better clarity by age as well. As long as a retiree is alive, they have statistical years ahead of them in the "longevity bow wave" to fund and thus balances continue to exist into those years as well. Once the retiree passes, those balances are a moot point for retiree income (though still needed if there is a surviving spouse), and that is when balances become bequests. What might those balances be by age? The third paradigm provides sharper focus on the range of possible answers to that question.

In other words, the first paradigm in retirement income determination was rote arithmetic. The second paradigm added Monte Carlo, for returns and standard deviation only, to a rote process (while retaining a rote single factor paradigm for both time periods and allocations) in recognition that market returns are not a single average, but a sequence of random unknown returns. The third paradigm is a deeper embrace of statistics and statistical processes to model in sharper focus retirement cash flows and balances by age as one ages; not to some single randomly selected age but using the longevity percentiles more strategically so the odds of outlining that rolling age also means the odds of outlining retirement money are low too.

These applied statistical principles also allow for more insightful preretirement planning as well, so that people may have deeper insights and better understanding of how to understand and sustain their lifestyle, to and through retirement. Retirement planning should include a seamless transition between accumulation years while working, and spending years while retired. Today's 2nd paradigm has a troublesome disconnect between the two phases which is attempted to be explained away by a "Retirement Red Zone" and temporary sequence risk exposures. Both come out of the same disconnected joining of these two phases; and both are eliminated when an age-based approach is used for both phases.

Better Focus … An analogy

The Hubble telescope, a tool that simply changed location of the telescope as a tool, brought deeper insights by changing location from earth's surface to space. The Hubble could look deeper into the past with much better clarity. The 3rd paradigm is simply repositioning the same Monte Carlo tool with more focus to look deeper into the future using many separate simulations unified through a data cloud comprised of all those separate solutions, in contrast to the capability today Monte Carlo provides with just one simulation at a time, thus resulting in better clarity into answering real people's deeper questions, anxieties, and concerns! The 3rd paradigm application of Monte Carlo is to do "all" the simulations at once up front, and using that output more efficiently where programming looks over the optimum simulation result by age and strings those cash flows and balances together from attained age all the way to the end of the longevity table in use (some go out to age 120).

What are the Three Paradigms of Retirement Income Planning?

I suggest deeper insights into retirement would come from a different paradigm, i.e., programming, that changes simulations from single factor simulations to all the factors simulations through the use of "data clouds" through which choices may be better compared by age (time periods that correspond to longevity derived periods). The result is cash flow and balance *modeling,* rather than one *simulation at a time, age by age, when one reaches a later age*.

Modeling is the same tool, i.e., Monte Carlo, however the tool is deployed more strategically to bring more focus on a narrower range of future outcomes through strategic use of simulation percentiles as opposed to those percentiles radiating out of one single simulation over one single time period. This is possible by using *iteration failure rates* as a control variable so that all simulations can be compared to each other through the use of that control variable. The paradigm shift includes the realization that iteration failure rates are not probability of failure as presently interpreted.

Why is the third paradigm so long in coming?

The third paradigm, when it comes, will bring more focus and clarity to retirement planning *by age*. At the moment, the profession is stuck in the one-by-one simulation paradigm over a single fixed time frame, of whatever randomly chosen time period. It will take "Gordion Knot," (Stutman, 2021b) with outside-of-the-box thinking and approaches, different from present profession's and software programmer's thought processes. There is no project "silo" to advance modeling as a methodology since today's silos are separately compartmentalized within, and between programming, planning, investing and advising professions. The profession's issue is how to get organization silos to work better together, both within and between organizations. There are many silos, or "firehouses," within, and between, organization that need to come together to form a "new way" of thinking and operating. (Cooper, 2022)

Silos aren't only within and between different functional expertise's, but also within and between organizations, inhibit and prevent advancements through cross pollination of ideas. A cross silo process (Heath 2020) should be developed to address moving the multi-profession disciplines of planning and programming into the statistical and age-based modeling paradigm; and the transition process should begin with advisors asking the programmers to develop and support the statistical age-based modeling paradigm. In other words, multidisciplinary and interdisciplinary approaches are necessary when more than one organization or functional expertise are involved.

The profession has become stuck in the Sigmoid Curve (Stutman, 2021a). The Sigmoid Curve has not shifted into a new phase since the present paradigm held so strongly by all players (academics, researchers, practitioners, programmers, and others) have not allowed that shift, or even considered shifting paradigms through advancing methodology, processes, and thinking about the retirement aging process and its' effects on retirement income as one ages.

To date, no one is thinking in terms of the third paradigm – which goes deeper into answering real retiree questions about their future at various future ages, as well as what heirs may be looking at, if that's a retiree goal too, *by future age.* Modeling shows how one can spend a dollar once – so is that dollar spent during early ages or retained for future ages. This means there's a direct connection between spending and balances at all ages and modeling illustrates the effect of spending on balances at all ages. Just as in the spending years, where each spending year is simulated separately from the others over its' unique time period (comparing each allocation to determine the optimal cashflow), each accumulation year is also simulated separately from the others over its' unique time period and summed over selected simulation percentiles around the median percentile with allocation comparisons too (of research interest on this accumulation point – are the "end of year one" simulations the same over all working year simulations, or do they too slowly adjust). Final note on the accumulation years: simulations simulate the fact that each year's worth of savings grows to a different sum because they have different time frames to grow in the first place … i.e., the first contribution grows more than the last simply because of time, even with the very same rate of return … so why not simulate each year separately too? Probability Management SIPmath demonstrates that statistics sum too (Savage, 2022a, 2022b). Those who might argue that monthly contributions would grow differently than annually – true; however, the volatility of returns would wash over that nuance much like tides washing away footprints in the sand, so an annual modeling approximation with percentile evaluation bwould work.

What is missing in today's programming and approaches is a more focused method to measure and monitor spending health (cash flows and balances) through retirement, including a method to evaluate and compare how future spending effects the present or how present spending ripple effects into the future. Also missing is the accumulation years and transition into the spending years, let alone at what age that transition may be expected and insights into what meaningful adjustments may change that outlook, in other words a "retirement feasibility timeline," where the ripple effect of adjustments by age are shown graphically without having to separate simulations with different assumptions.

So, what to do?

The need for better retirement income planning – solved with an age-based model focus.

Science, and its' application, in all the professions have advanced over the past decades. Look at how the dogma in medicine has changed from bloodletting to laser surgery as new knowledge and technology incrementally led to paradigm shifts. The same can be said in many fields of study. The science, and software programming to support it, for retirement income planning has advanced little in comparison. Drs didn't invent lasers, but they use them, the same with robotics and many other advancements. Other professions have done the same by looking outside their own organizational and corporate silos into other disciplines that at first blush appear unrelated. Part of the issue is that advisers, and consumers, are unaware that they should ask for more modernized software programming based on modern statistical applications.

It is time to model aging *and* spending, in not only thought, but practice supported by software programming, and bring the modern versions of science and mathematics of statistics (Savage, 2012, 2021a, 2021b, 2022a, 2022b) into the sphere of retirement planning understanding that the retirement timeframe is not a fixed or static, single factor, timeframe, but rather a connected series of rolling time frames of aging. Modeling should reflect those *connected* rolling time frames of aging. Retirees *age through* life with prior spending decisions affecting subsequent spending and balances.

The same can be said about utilizing consumer spending statistics (Blanchett 2014) by age and category so retirees can have a statistical point of reference by age what they may need to plan for looking ahead (the boat's bow wave). "The results of the analysis suggest that although the retiree consumption basket is likely to increase at a rate that is faster than general inflation, actual retiree spending tends to decline in retirement in real terms. This decrease in real consumption averages approximately 1 percent per year during retirement. A 'retirement spending smile' effect is noted. This finding has important implications when estimating retirement withdrawal rates and determining optimal spending strategies." (Blanchett 2014)

What's missing for the third paradigm to come to fruition is a much fuller embrace of statistics and their strategic percentile use, by age, for each set of statistics relevant to deeper insights with a better focus on a narrower range of possible outcomes into retirement measurements and monitoring, not only up to and at the moment of retirement, but throughout retirement regardless of age as well.

A true model goes from the early *ages*, up to and through the transition into retirement, and using the same modeling methodology, throughout all the statistically possible *ages* in retirement too.

How about broadening and deepening the retirement accumulation and spending discussions with modeling that illustrates the above concepts in simple illustrations … a picture says 1,000 words.

All of the above is *only possible IF the necessary group of people across various professions involved get together, outside their organizational silos, to make it happen* (Heath 2020). Otherwise, the hunt and peck planning of the 2nd paradigm as it exists today will continue ad infinitum.

Concepts and statistics are all available now. Who is going to bring it all together as a useful tool for advisers? Can the dogma of the 2nd paradigm be overcome to shift to the 3rd? Where is the next paradigm shift going to start? Who (what combination of groups) will start it? When?

New insights come from changing old thoughts and understanding.

Nobody has yet applied the concepts and principles of the 3rd paradigm (though Ken Steiner, a retired actuary, has long been a proponent, albeit through a deterministic actuarial process). Nobody has yet disproved the age-based application of longevity statistics and strategic use of their percentiles either. The dogma of the 2nd paradigm is too imbedded and strongly held. So the issues with the second paradigm persist, primarily the **second paradigm has no cohesive methodology that connects and smoothly transitions** from the working accumulation phase with the retirement spending phase. ***The age-based methodology discussed above in the third paradigm does just that since it uses the same methodology from the first savings year while***

working, through the last spending year in retirement (and also provides a sharper focus on potential bequests to heirs at any age as well). The same statistical principles also provide a more mathematically robust method to calculate key decision points, through a strategic application of iteration failure rates, to measure and monitor spending health when markets are stressed; referring to the present conditions rather than a rule of thumb approach measured from the past.

People can more easily adjust their behavior when they can more clearly visualize and see their future as well as how decisions today improve or deteriorate that future.

Applying more sophisticated models based on a fuller application of statistics would bring more modern capabilities with a better focus to both advisers and their clients. It is past time the financial planning profession advance their thoughts, sciences, and applications as well, just as other professions have done the past 3 decades when the planning profession's second paradigm shift began and the dogma of the first paradigm shifted.

The profession is slowly being left behind while the applicable sciences useful to the profession advance. Worse, left behind because the applicable sciences are not integrated into a model relevant to aging and the issue of measuring and monitoring the health of retiree spending. Processes, not products, support the modeling approach since processes are adaptable, while products once bought by a retiree are not. I'll be bold and state that the nature of planning won't advance without a sharper focus on modeling aging itself, simply because that *is retirement.*

The longer to adopting a new paradigm, the further behind the profession falls as the speed of change accelerates (Mauri 2016).

A possible 4th Paradigm to emerge from the adoption of the 3rd where artificial intelligence, mimicking the human manual programming, statistical data gathering, and data processing using AI's subset of machine learning to perform the desired cash flow and balances, and multiple simulations to form the data by age as described above in the 3rd paradigm, i.e., applying the broader concepts of artificial intelligence "big data." The 4th Paradigm gathers the statistical data and synthesizes it into the programming the human programmers continue to refine programming for human advisers to continue to apply insights for human decision making. In other words, statistical data gathering and initial processing of consumer spending, portfolio statistics, longevity statistics, etc., so humans don't need to perform those data gathering functions. Humans free up time to focus on final data refinements and programming updates and refinements. The programmer also refines programming hand in hand with adviser feedback working with clients and changing tax laws, etc. The role of the advisor would be more focused on bigger picture customizing, reviewing, planning contingency options, and overall advising of the plan with the clients as they age. In other words, a stronger move towards advising and planning for people. But it's tempting to skip so the profession has to go through and refine the third before the fourth paradigm is possible.

CONCLUSIONS

- Current 2nd paradigm term "Probability of Failure" is mislabeling the concept of Iteration Failure Rates of simulations used to calculate a solution to the mixture of variables used in the simulation.
- The 2nd paradigm view that the simulation's solutions lie at the end of the simulation period misdirects the observations away from where the true solution lies, which is at the beginning of the simulation, through the use of iteration failure rate as the simulation's control variable.
- At least one input variable needs to be the control variable. Simulation control variables are used so that each solution from different simulation mixture of inputs may be compared properly to the solution of all other simulations performed with their own unique mixture of inputs.
- The lack of a control variable in both planning and software programming leads to results that cannot be properly compared to each other to determine outcomes and make informed planning decisions.
- Presently, allocations are generic and non-optimized which leads to suboptimal solutions because allocations are not efficiently optimized which results in non-optimal drawdowns.
- Allocations are chosen for retirees, essentially randomly when sub-optimal, rather than compared methodically to determine the optimal allocation by age, and subsequently reevaluated and updated as the retiree ages.
- Inefficient allocations inadvertently force retirees to save more since drawdown rates are less relative to an efficient allocation, therefore requiring a higher balance to net the same cashflows relative to an efficient allocation for the same age (time-period).
- Time periods for drawdowns presently are not age-based, which results in more random application of distribution periods in the planning process as well as for software programming for that planning.

What are the Three Paradigms of Retirement Income Planning?

- The so-called retirement red zone doesn't exist. Downside risk is ever present regardless of age. Iteration failure rate (IFR) is more effective to measure spending health.
- When time periods are viewed as "time in" or "time since" retirement, that is a clear signal that a single computational or simulation process was used (2^{nd} paradigm).
- Presently, age is not modeled, nor is aging in retirement modeled, due to a lack of systematic and strategic use of longevity percentile statistics to properly align appropriate distribution time periods to each attained age in the modeling process.
- Aging, and thus models replicate aging, need to recognize that aging is a connected series of time events where prior decisions and actions ripple through into later ages into the future. A single simulation approach does not replicate that ripple effect correctly.
- Cash flows and balances *within* a simulation are not the same as cash flows and balances *between* simulations.
- An age-based process provides a year-by-year unified transition between working accumulation years and retirement drawdown years using the same methodology that models real life where the direction of cash flows simply switches.
- An age-based process also provides a year-by-year transition between ages during both the accumulation and drawdown years.
- Modeling aging retirement will go a long way towards providing a more focused view of future cash flows and portfolio balances *while the retiree ages through time.*
- Aging needs to be modeling since time, presently assumed away, has a large impact on drawdown rates, and thus the process of aging's effects is presently ignored.
- A multidisciplinary and interdisciplinary approach of mathematics, statistics, technology, expertise, and management often leads to new capabilities.
- Academics, researchers, practitioners, programmers and everyone else all operate with the same paradigm.
- As seen in many fields of study, with a paradigm shift resulting from new knowledge, insights and understanding, much of an earlier paradigm's thoughts and approaches are no longer applicable as the shift to new thoughts and approaches are realized and take hold as witnessed in many other fields of study.

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Appendix 1. Example efficient allocations with characteristics and asset class data incorporated.

Target Band

Asset Class	Historical Return Index

The Risk-Based Portfolio was selected from this list of Portfolios, based upon the risk assessment. The Risk Band is comprised of the portfolio(s) that could be appropriate for you, based upon the Risk-Based Portfolio indicated. The Target Portfolio was selected by you. Refer to the Worst 1-Year Loss and Standard Deviation columns in the chart below to compare the relative risks of your Current Portfolio to the Target Portfolio.

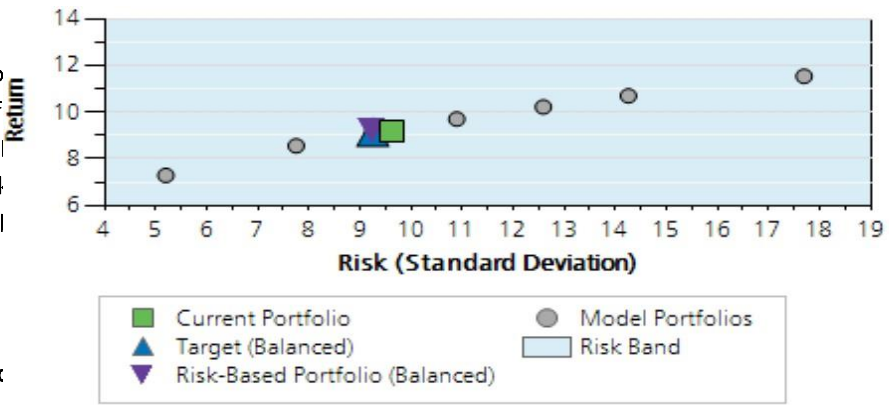
Portfolios	Name	Cash	Bond	Stock	Alternative	Fixed Index	Average Return	Worst One Year	Standard Deviation
	Defensive	0.50%	79.50%	18.00%	2.00%	0.00%	7.29%	-3.35%	5.20%
	Conservative	0.50%	59.50%	38.00%	2.00%	0.00%	8.56%	-12.73%	7.75%
▼ ▲	Balanced	0.50%	49.50%	47.00%	3.00%	0.00%	9.15%	-17.41%	9.25%
■	Current	0.52%	47.04%	49.32%	3.12%	0.00%	9.22%	-18.44%	9.61%
	Moderate	0.50%	39.50%	57.00%	3.00%	0.00%	9.71%	-22.10%	10.90%
	Moderately Aggressive	0.50%	29.50%	67.00%	3.00%	0.00%	10.23%	-26.80%	12.59%
	Aggressive	0.50%	19.50%	76.00%	4.00%	0.00%	10.71%	-31.47%	14.26%
	Highly Aggressive	0.50%	0.00%	95.50%	4.00%	0.00%	11.55%	-40.65%	17.70%

Risk Band ■ Current ▼ Risk-Based ▲ Target

Return vs. Risk Graph

When deciding how to invest your money, you must determine the amount of risk you are wil assume to pursue a desired return. The Return versus Risk Graph reflects a set of portfolio assume a low relative level of risk for each level of return, or conversely an optimal return f degree of investment risk taken. The graph also shows the position of the Risk Band, Target, Risk-I and Custom Portfolios. The positioning of these portfolios illustrates how their respective risk returns compare to each other as well as the optimized level of risk and return represented I Portfolios.

This graph shows the relationship of return and risk for each Portfolio in the chart above.



See Important Disclosures section in this Report for explanations of assumptions, limitations, methodc

Appendix 1. Example efficient allocations with characteristics and asset class data incorporated.

Asset Class	Historical Return Index
U.S. Total Stock Market	CRSP Deciles 1-10 Index (1972-1978). Russell 3000 TR USD (1979-2020).
U.S. Large Growth Stocks	Fama/French US Large Growth Index (ex utilities)(1972-1978). Russell 1000 Growth TR USD (1979-2019).
U.S. Large Neutral Stocks	S&P 500 Index (1972-1978). Russell 1000 TR USD (1979-2019).
U.S. Large Value Stocks	Fama/French US Large Value Index (ex utilities) (1972-1978). Russell 1000 Value TR USD (1979-2020).
U.S. Small Growth Stocks	Fama/French US Small Growth Index (ex utilities) (1972-1978). Russell 2000 Growth Index (1979-2019).
U.S. Small Neutral Stocks	CRSP Deciles 6-10 Index (1972-1978). Russell 2000 TR USD (1979-2020).
U.S. Small Value Stocks	Fama/French US Small Value Index (ex utilities)(1972-1978). Russell 2000 Value Index (1979-2019).
International Total Stock Market	MSCI World ex USA NR USD (1972-1994), MSCI World ex USA IMI NR USD (1994-2019)
International Large Growth Stocks	MSCI World ex USA NR USD (1972-1974). MSCI World Ex USA Growth NR USD (1975-2019).
International Large Neutral Stocks	MSCI World ex USA NR USD (1972-2019).
International Large Value Stocks	MSCI World ex USA NR USD (1972-1974). MSCI World Ex USA Value NR USD (1975-2020).
International Small Growth Stocks	Dimensional International Small Cap Index (1972-1989). S&P Developed Ex US Small Growth TR (1990-1994). MSCI World Ex USA Small Growth NR USD (1995-2019).
International Small Neutral Stocks	Dimensional International Small Cap Index (1972-2000). MSCI World Ex USA Small Cap NR USD (2001-2020).

Appendix 1. Example efficient allocations with characteristics and asset class data incorporated.

Asset Class	Historical Return Index
International Small Value Stocks	Dimensional International Small Cap Index (1972-1981). Dimensional International Small Cap Value Index (1981-1994). MSCI World Ex USA Small Value NR USD (1995-2019).
Emerging Markets Total Stock Market	MSCI Pacific Ex Japan NR USD (1972-1987). MSCI EM GR USD (1988-1998). MSCI EM
Emerging Markets Large Value Stocks	NR USD (1999-2020). Fama/French US Large Value Index (ex utilities) (1972-1978). Russell 1000 Value TR
U.S. Short Government Bonds	USD (1979-2020). IA SBBI US 1 Yr Trsy Const Mat TR USD (1972-1977). BofAML US Treasuries 1-3 Yr TR
U.S. Intermediate Government Bonds U.S. Long Government Bonds	USD (1978-1982). BofAML US Trsy/Agcs AAA 1-3 Yr TR USD (1983-2019). IA SBBI US IT Govt TR USD (1972-1972). Barclays US Government TR USD (1973-2019) IA SBBI US LT Govt TR USD (1972-1972). Barclays US Government Long TR USD (1973-2019)
U.S. Short Investment Grade Bonds	50% IA SBBI US 1 Yr Trsy Const Mat and 50% IA SBBI US IT Govt. (1972-1984), 50% IA SBBI US 1 Yr Trsy Const Mat and 50% Citi WGBI 1-5 Years (hdg) (1985-1986), 50% BofA ML 1-3 yr US Corp/Govt Index, and 50% Citi WGBI 1-5 Years (hdg) (1986-2020)
U.S. Intermediate Investment Grade Bonds	IA SBBI US IT Govt TR USD (1972-1972). Barclays US Govt/Credit TR USD (1973-1975).
U.S. Long Investment Grade Bonds	Barclays US Agg Bond TR USD (1976-2019). IA SBBI US LT Corp TR USD (1972-1972). Barclays US Long Credit TR USD (1973-2019).
U.S. Short Municipal Bonds	IA SBBI US 1 Yr Trsy Const Mat TR USD (1972-1986). BofAML US Corp&Govt 1-3 Yr TR
	USD (1987-2019).

Appendix 1. Example efficient allocations with characteristics and asset class data incorporated.

Asset Class	Historical Return Index
U.S. Intermediate Municipal Bonds	IA SBBI US LT Corp TR USD (1972-1980). Barclays Municipal TR USD (1981-2019).
U.S. Long Municipal Bonds	U.S. 30-day Treasury Bills (1926-2016)
U.S. Inflation-Protected Bonds	IA SBBI US LT Govt TR USD (1972-1997). Barclays US Treasury US TIPS TR USD (1998-2019).
U.S. High-Yield Bonds	IA Barclays US HY Corporate Bonds (1972-1983). Barclays US Corporate High Yield TR USD (1984-2019).
Global Short Bonds	IA SBBI US IT Govt TR USD (1972-1984). Citi WGBI 1-5 Yr Hdg USD (1985-2019).
Global Intermediate Bonds	IA SBBI US IT Govt TR USD (1972-1984). Citi WGBI Hdg USD (1985-2019)
Real Estate	FTSE NAREIT All Equity REITs TR USD (1972-1986). DJ US Select REIT TR USD (1987-2020).
Cash & Cash Alternatives	IA SBBI US 30 Day TBill TR USD (1972-1977). BofAML US Treasury Bill 3 Mon TR USD (1978-2020).
Commodities	S&P GSCI TR USD (1972-1990). Bloomberg Commodity TR USD (1991-2019).
Market Neutral	U.S. 30-day Treasury Bills (1926-2016)
Managed Futures	U.S. 30-day Treasury Bills (1926-2016)
Reinsurance	U.S. 30-day Treasury Bills (1926-2016)
Alternative Lending	U.S. 30-day Treasury Bills (1926-2016)
Diversified Alternatives	U.S. 30-day Treasury Bills (1926-2016)
Conservative Allocation	80% IA SBBI US IT Govt TR USD, 20% MSCI World NR USD (1972-1972). 80% Barclays US Govt/Credit TR USD, 20% MSCI World NR USD (1973-1975). 80% Barclays US Agg Bond TR USD, 20% MSCI World NR USD (1976-2019)
Moderate Allocation	50% IA SBBI US IT Govt TR USD, 50% MSCI World NR USD (1972-1972). 50% Barclays US Govt/Credit TR USD, 50% MSCI World NR USD (1973-1975). 50% Barclays US Agg Bond TR USD, 50% MSCI World NR USD (1976-2019)

Appendix 1. Example efficient allocations with characteristics and asset class data incorporated.

Asset Class	Historical Return Index
Aggressive Allocation	20% IA SBBI US IT Govt TR USD, 80% MSCI World NR USD (1972-1972). 20% Barclays US Govt/Credit TR USD, 80% MSCI World NR USD (1973-1975). 20% Barclays US Agg Bond TR USD, 80% MSCI World NR USD (1976-2019)
Global Total Stock Market	MSCI World NR USD (1972-1994), MSCI ACWI IMI NR USD (1994-2019)
Global Total Developed Stock Market	MSCI World NR USD (1972-1994), MSCI World IMI NR USD (1994-2019) Other Assets S&P 500 (Price
Return) (1972-2019)	
Fixed Index 3% Fixed	

Advisory fees may vary. Input of an advisory fee will result in the decrease of a simulated portfolio's overall value.